

**DEVELOPING A COAL QUALITY EXPERT:
COMBUSTION AND FIRESIDE PERFORMANCE
CHARACTERIZATION FACTORS**

**TOPICAL REPORT ON COALS FROM
MISSISSIPPI POWER'S WATSON STATION**

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PREPARED BY

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To Distribution:

Attached is our final report, DEVELOPING A COAL QUALITY EXPERT: COMBUSTION AND FIRESIDE PERFORMANCE CHARACTERIZATION FACTORS, a topical report on coals that were burned on Mississippi Power's Watson Station. The report covers results from pilot scale testing and from our boiler performance modeling tests.

Our objective in conducting pilot scale tests and conducting the boiler performance modeling studies is to provide information for algorithm development, primarily in the areas of slagging and fouling and also for fly ash erosion and boiler performance. The information, which is now summarized in the attached report, was previously supplied to cognizant personnel at UND EERC and PSIT, our subcontractors who are working on fouling and slagging algorithm development, respectively.

Included in the Appendix of the report are facility descriptions, information from the scanning electron microscopy (SEM) analysis and procedures for the SEM analysis, and all detailed information from pilot scale testing.

Sincerely,

ABB COMBUSTION ENGINEERING, INC.

R. W. Borio
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Attachment
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ABB Power Plant Laboratories

DEVELOPING A COAL QUALITY EXPERT: COMBUSTION AND FIRESIDE PERFORMANCE CHARACTERIZATION FACTORS

TOPICAL REPORT ON COALS FROM
MISSISSIPPI POWER'S WATSON STATION

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EXECUTIVE SUMMARY

The overall objective of the Coal Quality Expert (CQE) Clean Coal I Program is the development and validation of a comprehensive PC-based expert system for evaluating the impacts of coal quality on total power plant generating costs. This expert system will allow assessment of overall plant economics when evaluating the various emissions control strategies including cleaning, blending and switching options.

A key part of the CQE program is the development of sub-models to predict the effects of coal quality on boiler performance under various operating conditions. Existing correlations between fuel properties and boiler performance are weak in several areas. These weaknesses are being addressed in this program through a combination of comprehensive bench-, pilot- and full-scale testing. Performance and validation data for a series of coals fired in selected utility boilers are being generated by laboratory and field tests.

Included in ABB Combustion Engineering's (ABB CE's) work scope is the generation of information to facilitate the formulation of sub-models to predict ash slagging and fouling and subsequent impacts on boiler performance. This is an area of primary importance because of the poor reliability of current predictive indices, and the strong influence which ash deposition can have on overall boiler performance and power generating costs. In order to predict slagging and fouling, modeling efforts will apply a more fundamental approach which subdivides the ash deposition process to focus on ash formation, transport and deposition, deposit strength development and response to soot blowing, and deposit heat transfer effects. Pilot-scale testing in ABB CE's Fireside Performance Test Facility (FPTF) is used to facilitate the quantification of these phenomena by providing a highly controlled combustion environment that allows systematic variation and effect of boiler operating conditions. The high level of control afforded by pilot-scale testing also provides a means to directly measure key performance parameters for development of cause-and-effect relationships. The

correlation of measured fuel properties to physical and thermal properties of ash deposits is an essential element of the slagging/fouling algorithm development.

This report summarizes the bench- and pilot-scale test results along with results from the boiler performance modeling (combustion reactivity as well as computational boiler performance modeling) which was conducted at ABB CE for coals burned at Mississippi Power's Watson Station, Unit 4. Coals tested included Jader coal, an Illinois #5 coal which is the baseline coal at Watson, and Island Creek coal, a Kentucky #11 coal which is an alternate coal used at Watson. Results from field testing at Unit 4 were used to assess and substantiate findings from bench- and pilot-scale tests as well as results from the boiler performance model evaluation. The primary purpose of this report is to summarize key information required for further sub-model development efforts.

Detailed fuel property characterization was conducted by ABB CE and by the University of North Dakota's Energy and Environmental Research Center (EERC). In general, the Jader and Island Creek coals were found to be very similar in chemical characteristics. The only significant differences were the somewhat higher ash level and slightly greater higher heating value in the Jader coal.

Pilot-scale testing at ABB CE quantified coal ash related effects on performance. Deposit formation, growth and thermal effects were measured in both radiant and convective sections. The effects of key boiler operating conditions on ash deposits were determined and limitations for continuous operation were established for each test coal. The Jader coal exhibited better slagging (lower furnace deposits) performance than the Island Creek coal. The Jader coal produced deposits in the lower furnace which remained cleanable at a test furnace thermal input of 4.0 MBtu/hr and peak gas temperatures up to 3010 °F. The Island Creek coal, by contrast, produced lower furnace deposits which were cleanable only up to 3.6 MBtu/hr and gas temperatures of 2910°F. Average thermal conductances ($k/\Delta x$), as measured during pilot-scale testing, were somewhat higher for deposits from the Jader coal as

compared to the Island Creek coal deposits. This is consistent with field testing results; the Jader coal, for example, resulted in lower furnace outlet temperatures, implying that heat transfer (through the ash deposits) was better in the Jader case than with the Island Creek case.

Excess air was shown to have a significant effect on the nature of lower furnace deposits when firing both the Jader and Island Creek coals. Specifically, decreasing excess air levels (20% to 10%) reduced the critical thermal input and maximum temperature for adequate deposit cleanability to 3.6 MBtu/hr and 2910°F for the Jader coal and 3.2 MBtu/hr and 2830°F for the Island Creek coal.

Convective pass deposition rates were slightly higher for the Jader coal compared to the Island Creek coal. The Jader coal convection pass deposits-to-tube bonding strength values were slightly lower (less tenaciously bonded) than those from the Island Creek coal, however, bonding strength values for both coals were low, implying that normal sootblowers would provide adequate cleaning. Bonding strength values taken during field testing were consistent with the values obtained during FPTF testing.

Boiler performance modeling and field test results were consistent and corroborated pilot-scale conclusions, namely that the Jader coal was lower slagging than the Island Creek and that the Island Creek coal would have less buildup in the backpass when compared to the Jader coal. The Boiler Performance Model provided a data quality check of field test measurements to insure data were consistent and reasonable. The Boiler Performance Model also provided information on boiler operating conditions and performance parameters not directly measured during field testing. Modeling results showed field test FOT measurements to be approximately 200-300°F lower than what would be required to close the heat balance. The calibrated Boiler Performance Model predicted field FOTs which were consistent with overall boiler performance data and accurately identified changes in performance such as wall conductance ($k/\Delta x$) and surface effectiveness factors (SEF) values using FPTF results.

Convective tube erosion rates due to fly ash impingement were evaluated for the subject coals during pilot-scale testing. Erosion rates for the two coals were very similar with the Jader being slightly more erosive, however, both coals showed very low erosion relative to most other U.S. coals.

Overall, a great deal of detailed, quantitative fuel and performance data were collected during this series of Mississippi Power Watson coal tests. Ash slagging and fouling data were obtained over a range of utility boiler operating conditions. At conditions representative of the Watson unit, pilot-scale results were generally consistent and compared very favorably with field test results with the important, added advantage of providing more detailed quantitative information than can be reasonably obtained from field testing. Fuel property and performance results detailed in this report, along with those results from other fuels tested under this project, provide a sound basis for development of key sub-models for the Coal Quality Expert.

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Table of Contents

Section 1

1.0 INTRODUCTION	1
1.1 PROGRAM OVERVIEW	1

Section 2

2.0 PILOT-SCALE TESTING	5
2.1 TEST FUELS	5
2.2 FIRESIDE PERFORMANCE CHARACTERISTICS	7
Test Conditions	11
Furnace Slagging	17
<u>Simulated Waterwall Deposits</u>	17
Convective Pass Fouling	47
Fly Ash Erosion	54

Section 3

3.0 BOILER PERFORMANCE MODELING	56
3.1 DESCRIPTION OF WATSON UNIT 4	57
3.2 BOILER OPERATION	58
3.3 COAL SOURCE	60
3.4 BOILER PERFORMANCE PROGRAM DESCRIPTION	62
3.5 BOILER PERFORMANCE PROGRAM CALIBRATION PROCEDURE	65
Calibration of Watson Unit 4	69
3.6 BOILER PERFORMANCE WITH ISLAND CREEK COAL	76
Performance Prediction Procedure	76
Comparison of Baseline Calibration and Alternate Performance Projection	81
Evaluation of Full-Scale and Pilot-Scale Data for Island Creek Coal	84
3.7 FIELD AND PILOT-SCALE CORRELATION UPDATE	86

Section 4

4.0 CONCLUSIONS	90
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Appendix A - Facility Descriptions	
Appendix B - UND SEM Procedure	
Appendix C - Detailed CCSEM and Chemical Fractionation Results	
Appendix D - CE Pilot-Scale (FPTF) Data	

List of Figures

Figure 1.1	Slagging and Fouling Algorithm Development Schematic	2
Figure 2.1	Coal Particle Size Distributions For Watson Coals	11
Figure 2.2	Fireside Performance Test Facility	12
Figure 2.3	Typical FPTF Variation of Temperature Profiles with Distance During Test Firing of the Watson Fuels	15
Figure 2.4	Typical Radial and Axial Gas Temperatures in the FPTF While Firing Watson Fuels	15
Figure 2.5	Heat Flux Comparison Between the FPTF and the Watson Unit 4	16
Figure 2.6	Comparison of Bulk Gas Residence Times at Similar Loads for Watson Coals	16
Figure 2.7	Schematic of Waterwall Panel and Deposit	17
Figure 2.8	Jader Coal Heat Flux Summary	20
Figure 2.9	Island Creek Coal Heat Flux Summary	21
Figure 2.10	Watson Fuel Testing Heat Flux Summary At Similar Firing Rates	22
Figure 2.11	FPTF Waterwall Panel Heat Flux While Testing Jader Coal	24
Figure 2.12	FPTF Waterwall Panel Heat Flux While Testing Jader Coal	25
Figure 2.13	FPTF Waterwall Panel Heat Flux While Testing Jader Coal	26
Figure 2.14	FPTF Waterwall Panel Heat Flux While Testing Island Creek Coal	27
Figure 2.15	FPTF Waterwall Panel Heat Flux While Testing Island Creek Coal	28
Figure 2.16	FPTF Waterwall Panel Heat Flux While Testing Island Creek Coal ...	29
Figure 2.17	Lower Furnace Deposit Buildup - Time Sequencing (Jader Test 1) ...	31
Figure 2.18	Lower Furnace Deposit Buildup - Time Sequencing (Jader Test 2) ...	32
Figure 2.19	Lower Furnace Deposit Buildup - Time Sequencing (Jader Test 3) ...	33
Figure 2.20	Lower Furnace Deposit Buildup - Time Sequencing (Jader Test 6) ...	34
Figure 2.21	Lower Furnace Deposit Buildup - Time Sequencing (Jader Test 7) ...	35
Figure 2.22	Lower Furnace Deposit Buildup - Time Sequencing (Jader Test 8) ...	36
Figure 2.23	Lower Furnace Deposit Buildup - Time Sequencing (Island Creek Test 1)	37
Figure 2.24	Lower Furnace Deposit Buildup - Time Sequencing (Island Creek Test 2)	38
Figure 2.25	Lower Furnace Deposit Buildup - Time Sequencing (Island Creek Test 3)	39
Figure 2.26	Lower Furnace Deposit Buildup - Time Sequencing (Island Creek Test 5)	40

Figure 2.27	Lower Furnace Deposit Buildup - Time Sequencing (Island Creek Test 6)	41
Figure 2.28	Lower Furnace Deposit Buildup - Time Sequencing (Island Creek Test 7)	42
Figure 2.29	Lower Furnace Deposit Buildup - Time Sequencing (Island Creek Test 8)	43
Figure 2.30	Panel Deposit Heat Balance and Thermal Conductance Measurement Technique	46
Figure 2.31	Bonding Strength Comparison of Watson Coals	48
Figure 2.32	Upper Furnace Deposit Buildup-Time Sequencing	50
Figure 2.33	Upper Furnace Deposit Buildup-Time Sequencing	51
Figure 2.34	Upper Furnace Deposit Buildup-Time Sequencing	52
Figure 2.35	Upper Furnace Deposit Buildup-Time Sequencing	53
Figure 2.36	Watson Erosion Comparison	55
Figure 3.1	Schematic Drawing of Watson Unit 4	59
Figure 3.2	Boiler Performance Program Domain	63
Figure 3.3	Boiler Performance Program Flowchart for Baseline Coal Calibration	67
Figure 3.4	HFOT Measurement Location On Watson Unit 4	70
Figure 3.5	EER HFOT Data From Watson Unit 4	71
Figure 3.6	Bonding Strength Measurement Location On Watson Unit 4	73
Figure 3.7	Radiation Heat Flux	75
Figure 3.8	Thermal Conductance vs. Flame Temperature, Jader Coal	75
Figure 3.9	Boiler Performance Flowchart For Performance Prediction	78
Figure 3.10	Thermal Conductance vs. Flame Temperature , Island Creek Coal	80
Figure 3.11	Thermal Conductance vs. Flame Temperature FPTF vs. Field, Island Creek Coal	87
Figure 3.12	FPTF vs. Field Thermal Conductance Correlation	88

List of Tables

Table 2.1	ASTM Standard Analyses of Watson Coals	8
Table 2.2	Generic Interpretation of Standard Bench-Scale Performance Indicators .	9
Table 2.3	Bench-Scale Performance Indices For Watson Fuels	10
Table 2.4	Test Matrix For Watson Coals	13
Table 2.5	Critical Conditions for Marginal Waterwall Panel 1 Deposits in the FPTF .	44
Table 2.6	Thermal Conductances of Deposits Generated at Various Elevations in the FPTF	47
Table 2.7	Erosion Results For Watson Coals	55
Table 3.1	Analyses of Watson Unit 4 Test Coals	61
Table 3.2	Calibration of Field Test Data for Jader Coal	68
Table 3.3	Watson Unit 4 Surface Effectiveness Factors	74
Table 3.4	Bench and Pilot-Scale Coal Quality Indicators	77
Table 3.5	Watson Unit 4 Comparison of Island Creek Coal to Calibrated Jader Results	82
Table 3.6	Watson Unit 4 Island Creek Coal Performance Results	85
Table 3.7	Data Summary For The Island Creek Coal	86
Table 3.8	Watson Unit 4 Surface Effectiveness Factors	86
Table 3.9	Thermal Conductance For Field And Pilot-Scale Testing	89

Section 1

INTRODUCTION

1.1 PROGRAM OVERVIEW

The overall objective of the Coal Quality Expert (CQE) Clean Coal I Program is the development of a Coal Quality Expert -- a comprehensive PC-based expert system for evaluating the potential for coal cleaning, blending and switching options to reduce emissions while producing the lowest cost electricity. A key part of the CQE program is the development of sub-models to predict the effects of coal quality on boiler performance under various operating conditions. Included in ABB Combustion Engineering's work scope is the generation of information to facilitate the formulation of a sub-model to predict slagging and fouling and its subsequent effect on boiler performance, and to predict combustion performance, specifically carbon burnout. In order to predict slagging and fouling, ash deposition processes must be defined and modeled. Ash formation, transport and deposition, deposit strength development and response to soot blowing and effect on heat transfer are the key processes which will be modeled. The correlation of measured fuel properties to physical and thermal properties of ash deposits is an essential element of the slagging/fouling algorithm development. The overall slagging and fouling algorithm development scheme is presented in Figure 1.1. Similarly, fuel reactivity parameters will be measured to form a database from which combustion predictions can be made. The generation of required information was obtained from a combination of bench-, pilot-, and full-scale testing which has been carried out on a series of coals and coal blends which were of interest to Mississippi Power at their Watson Station.

This report summarizes the bench- and pilot-scale test results along with results from the boiler performance modeling (combustion reactivity as well as computational boiler performance modeling) which was conducted at ABB Combustion Engineering (CE) for the coals obtained from Mississippi Power's Watson Station. Results from field testing at Unit 4 were used to substantiate findings from bench- and pilot-scale tests as well as results from the boiler performance model.

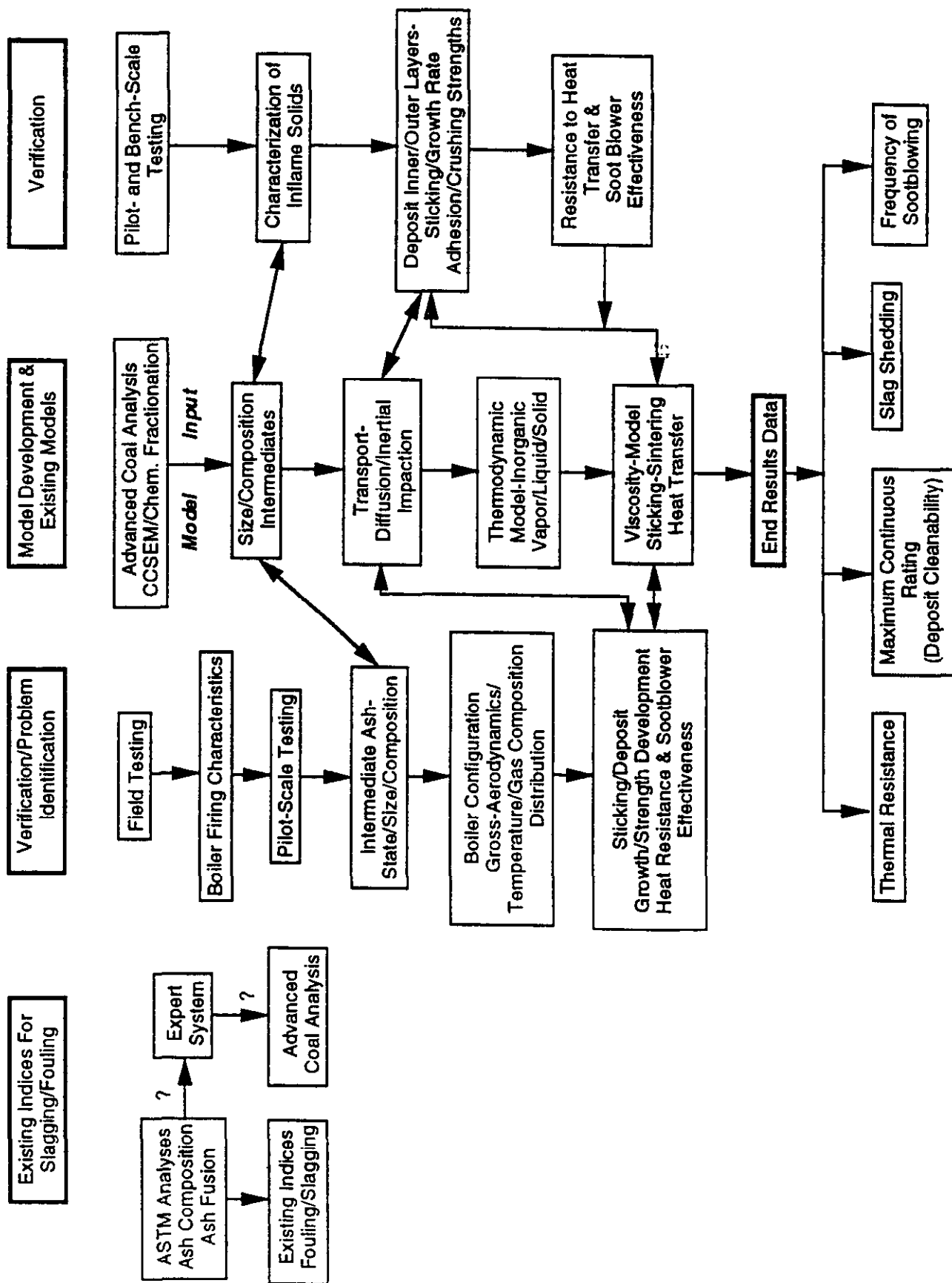


Figure 1.1 Slagging and Fouling Algorithm Development Schematic

Bench-scale testing was used to characterize combustion kinetic properties and ash deposition propensities of fuels burned in both full-scale and pilot-scale units. These fuels included a Illinois #5 coal (Jader) and a Kentucky #11 coal (Island Creek). Standard ASTM analyses were performed on these fuels, as were special analyses, including Computer Controlled Scanning Electron Microscopy (CCSEM), and Chemical Fractionation (CF). Special analyses were necessary to provide specific fuel and ash information on mineral size, associations and abundance not obtained through conventional ASTM analyses. Ignitibility and reactivity characteristics for the coals and their respective chars were measured to provide input necessary for the combustion performance computational models as well as for carbon burnout algorithm development.

Pilot-scale tests, performed in Combustion Engineering's Fireside Performance Test Facility (FPTF), were designed to closely match field unit furnace conditions. Pilot-scale testing allowed in-depth analysis of furnace deposits during and after formation under well-controlled conditions. Deposit formation, growth and thermal effects were characterized in both the radiant and convective sections of the FPTF; this information will be the basis of slagging and fouling-related algorithm development. Coal, deposit and ash samples generated in the FPTF were analyzed at the Energy & Environmental Research Center (EERC-UND) of the University of North Dakota using advanced methods of coal and coal ash analysis, however detailed analysis of the results were not possible due to budgetary constraints. The key objectives of the FPTF testing was to address cause and effect relationships of slagging and fouling deposition, and to quantify slagging and fouling for correlation with coal properties. Thermal and physical characteristics were to be separately analyzed and correlated to deposit strength and growth.

The boiler performance models, which can use bench-, pilot- and full-scale information, were applied to predict the performance of the two coals in Mississippi Power's Watson Station Unit 4. Calibration of the computational models with known baseline data allowed the prediction of boiler performance when firing alternate fuels. Computational models were used to supplement field data and provide more complete

boiler performance information. This boiler performance data, used in conjunction with the lab-scale data, provides the foundation for algorithm development.

Section 2

PILOT-SCALE TESTING

Pilot-scale tests were performed in order to evaluate the fireside characteristics of the test fuels in a manner where unit-specific effects (such as boiler design, upper furnace convective pass tube spacing, firing arrangement, etc.) could be eliminated, allowing an unbiased evaluation of fuel performance. Maintaining the same, or similar firing conditions, heat absorption, and temperature profiles in a full-scale unit to evaluate fuel performance while switching fuels is virtually impossible and can be very expensive. However, the pilot-scale allows for better control over the temperature profiles and heat fluxes, and is capable of modelling full-scale boiler phenomena in a controlled environment.

Comprehensive tests were conducted in C-E's Fireside Performance Test Facility (FPTF) to evaluate the combustion, furnace slagging, convective pass fouling and fly ash erosion characteristics of the fuels tested at the Watson Unit #4. Representative in-flame solids and ash deposit samples were collected during testing and analyzed using special techniques (Scanning Electron Microscopy, etc.) to enhance the fundamental understanding of mineral matter transformation and ash deposition, and to relate these to fuel mineral distributions and combustion conditions. The ultimate results of the pilot-scale data gathering and analysis shall aid in algorithm development for fouling and slagging routines which are able to model ash deposition, growth and thermal properties.

2.1. TEST FUELS

Two coals were evaluated for combustion and fireside performance in the FPTF. The fuels were Jader coal and Island Creek coal. The Jader coal is an Illinois #5 coal and the Island Creek coal is a Kentucky #11. The Jader coal is considered the baseline coal by Mississippi Power and the Island Creek coal is considered an alternate coal.

Coal samples were collected in 55 gallon drums during full-scale testing at Mississippi Power's Watson plant. The samples were obtained while the unit was on-line burning the test coal to ensure representative samples. The samples were then shipped to C-E for pilot- and bench-scale testing. Once on the C-E site all barrels of each coal were dumped and mixed to make a representative sample of each coal for testing.

The crushed coal obtained from the field (1/2" to 2" top size) was fed from a storage hopper to a C-E Model 271 bowl mill where it was pulverized to the desired fineness. The small, deep-bowl, single-journal (roller) mill was equipped with a direct gas-fired air heater to provide mill drying air. The pulverized coal was pneumatically transported to a cyclone collector where most of it was dropped into a storage hopper. Fines in the cyclone effluent were collected in a bag filter and returned to the storage hopper. Pulverized coal was fed into the FPTF with a belt-type gravimetric feeder combined with a rotary air lock which allowed the coal to be injected pneumatically at the burner front.

Coal samples were taken from the pulverized coal feeder at set intervals during FPTF testing to obtain representative samples of the pulverized coals for bench-scale testing. The analyses of the as-fired coal samples from the pilot-scale testing are reported in Table 2.1 . The analytical data on the two coals show that both coals were high sulfur coals, 2.9% and 3.1% sulfur on a dry basis for the Jader and Island Creek, respectively. The Jader and Island Creek coals are classified as bituminous coals and are similar in terms of composition. The major differences in the Jader and Island Creek coals are the ash content (8.8% vs. 7.0%, as-fired) and Hardgrove Grindability (66 vs. 55), there was also a small difference in higher heating value (HHV), 13121 and 12837 Btu/lb (as-fired) . The coals were very similar in terms of ash composition and ash fusibility temperatures.

The slagging and fouling characteristics of coals are commonly evaluated by indicators developed from standard ASTM tests such as ash fusibility temperatures,

base-to acid ratio, iron-to-calcium ratio, slagging and fouling indices. The generally established ranges for these indicators that are used to classify ash slagging and fouling tendencies of a coal are shown in Table 2.2.

Ash fusibility tests are widely used and are normally considered as some of the most important properties influencing slagging and fouling. Ash fusibility temperatures for the two coals were similar and were considered low. The low values would indicate that both coals would have high slagging and fouling potentials. Many of the other bench-scale indicators, such as base/acid ratio, silica/alumina ratio and fouling factor to name a few, were similar for the two coals because of the similar analyses. However, the indices were inconsistent in the predicted behavior of the coals. Table 2.3 presents the calculated bench-scale indices for the Jader and Island Creek coals.

The coal samples were also analyzed for their particle size distribution, the results of these analyses are shown in Figure 2.1. The pulverizer was adjusted until it produced a particle size distribution that was representative of the field particle size distribution. For the testing in the FPTF the fineness was kept around 70% -200 mesh, this corresponded to average particle sizes of 47.1 μ m and 55.6 μ m for the Jader and Island Creek coals, respectively.

2.2. FIRESIDE PERFORMANCE CHARACTERISTICS

The combustion, slagging, fouling and erosion characteristics of the test coals were evaluated in the upper and lower furnace sections of the FPTF. A schematic of the FPTF is shown in Figure 2.2. Combustion characteristics were evaluated by visual observation, carbon burnout and gas analysis. Slagging characteristics were evaluated using simulated waterwall tube panels located at four elevations in the lower furnace. Fouling characteristics were evaluated in the upper section of the

Table 2.1 ASTM Standard Analyses of Watson Coals

<u>Analysis</u>	<u>Jader</u>		<u>Island Creek</u>	
	<u>As Fired</u>	<u>Dry</u>	<u>As Fired</u>	<u>Dry</u>
Proximate, wt.%				
Moisture	1.9	-	3.6	-
Volatile Matter	35.2	35.9	38.2	39.6
Fixed Carbon	54.1	55.2	51.2	53.2
Ash	8.8	8.9	7.0	7.2
HHV, Btu/lb	13121	13375	12837	13316
Ultimate, wt.%				
Moisture	1.9	-	3.6	-
Hydrogen	4.9	5.0	5.0	5.2
Carbon	74.9	76.3	71.1	73.8
Sulfur	2.9	2.9	3.0	3.1
Nitrogen	1.5	1.5	1.6	1.6
Oxygen	5.1	5.4	8.7	9.1
Ash	8.8	8.9	7.0	7.2
Ash Loading, lb/MBtu	6.7	-	5.5	-
Forms of Sulfur, wt.%				
Sulfate (dry)	0.36		0.97	
Pyritic (dry)	0.76		0.17	
Organic (dry)	1.78		1.86	
Ash Fusibility, °F (Reducing Atmosphere)				
I.T.	1960		1960	
S.T.	2008		1999	
H.T.	2081		2041	
F.T.	2169		2147	
Temp. Diff. (F.T. - I.T.)	209		187	
Ash Composition, wt.%				
SiO ₂	49.4		44.5	
Al ₂ O ₃	19.2		19.1	
Fe ₂ O ₃	21.8		22.1	
CaO	2.3		4.2	
MgO	1.1		0.9	
Na ₂ O	0.3		0.9	
K ₂ O	2.1		2.2	
TiO ₂	1.0		1.1	
P ₂ O ₅	0.2		0.3	
SO ₃	2.6		3.9	
Ratios				
Base/Acid	0.40		0.47	
Fe ₂ O ₃ /CaO	9.48		5.26	
SiO ₂ /Al ₂ O ₃	2.57		2.33	

Table 2.1(Cont'd) ASTM Standard Analyses of Watson Coals

Jader		Island Creek	
<u>Particle Size Analysis</u>		<u>Particle Size Analysis</u>	
<u>Mesh Size</u>	<u>% Retained</u>	<u>Mesh Size</u>	<u>% Retained</u>
+2"	0.0	+2"	0.0
+1.5"	0.0	+1.5"	18.4
+1"	8.2	+1"	11.2
+3/4"	8.9	+3/4"	3.8
+1/2"	14.8	+1/2"	5.5
+1/4"	23.5	+1/4"	14.9
+4	6.1	+4	4.3
+8	15.8	+8	12.6
+16	10.7	+16	11.6
+30	7.0	+30	8.0
+50	3.0	+50	5.0
+100	1.0	+100	2.3
+200	0.5	+200	1.1
+325	0.2	+325	0.4
-325	0.3	-325	0.8

Table 2.2 Generic Interpretation of Standard Bench-Scale Performance Indicators

<u>Slagging</u>	<u>Low</u>	<u>Moderate</u>	<u>High</u>	<u>Severe</u>
Base/Acid Ratio	<0.4 or >0.7	← 0.4 to 0.7 →		
Iron/Calcium Ratio	<0.3 or >3.0	← 0.3 to 3.0 →		
Silica Percentage, Wt%	<30	← 30 to 82 →		>82
Slagging Index	<0.6	0.6 to 2.0	2.0 to 2.6	>2.6
Silica/Alumina Ratio	<1.7	← 1.7 to 2.8 →		>2.8
Fe ₂ O ₃ in 2.9 Sink	<55	55 to 70	70 to 85	>85
<u>Fouling</u>				
Fouling Factor	<0.2	0.2 to 0.5	0.5 to 1.0	>1.0
Alkalis in Coal	<0.3	0.3 to 0.45	0.45 to 0.6	>0.6
Sodium in Ash	<0.5	0.5 to 1.0	1.0 to 2.5	>2.5

Table 2.3 Bench-Scale Performance Indices For Watson Fuels

<u>Slagging</u>	<u>Jader</u>		<u>Island Creek</u>	
	<u>Value</u>	<u>Potential</u>	<u>Value</u>	<u>Potential</u>
Base/Acid Ratio	0.40	High	0.47	High
Iron/Calcium Ratio	9.48	Low	5.26	Low
Silica Percentage, Wt %	49.4	Mod.	44.5	Mod.
Slagging Index	0.6	Mod.	0.75	Mod.
Silica/Alumina Ratio	2.57	High	2.33	High
Ash Softening Temp., °F	2008	High	1999	High
Ash Fluid Temp., °F	2169	High	2147	High
Fe ₂ O ₃ in 2.9 Sink	85.0	High	80.9	High
<u>Fouling</u>				
Fouling Factor	0.12	Low	0.42	Mod.
Alkalis in Coal	0.21	Low	0.43	Low
Sodium in Ash	0.3	Low	0.9	Mod.
Ash Initial Deformation Temp., °F	1960	High	1960	High
Ash Softening Temp., °F	2008	High	1999	High

FPTF where probe banks are located. From the convective section of the furnace, the flue gas is introduced into a high-velocity section where an irradiated coupon is exposed to the entrained ash particles as a measure of erosion wear.

Overall, the combustion characteristics of the two coals tested in the FPTF were good. Stable flames were obtained and very few sparklers (glowing, incompletely burned carbon particles) were observed during testing. Chemical analyses of the isokinetically-collected fly ash indicated that in all cases the carbon burnouts were high and the carbon conversion efficiencies were greater than 99.9% for both coals at all conditions tested.

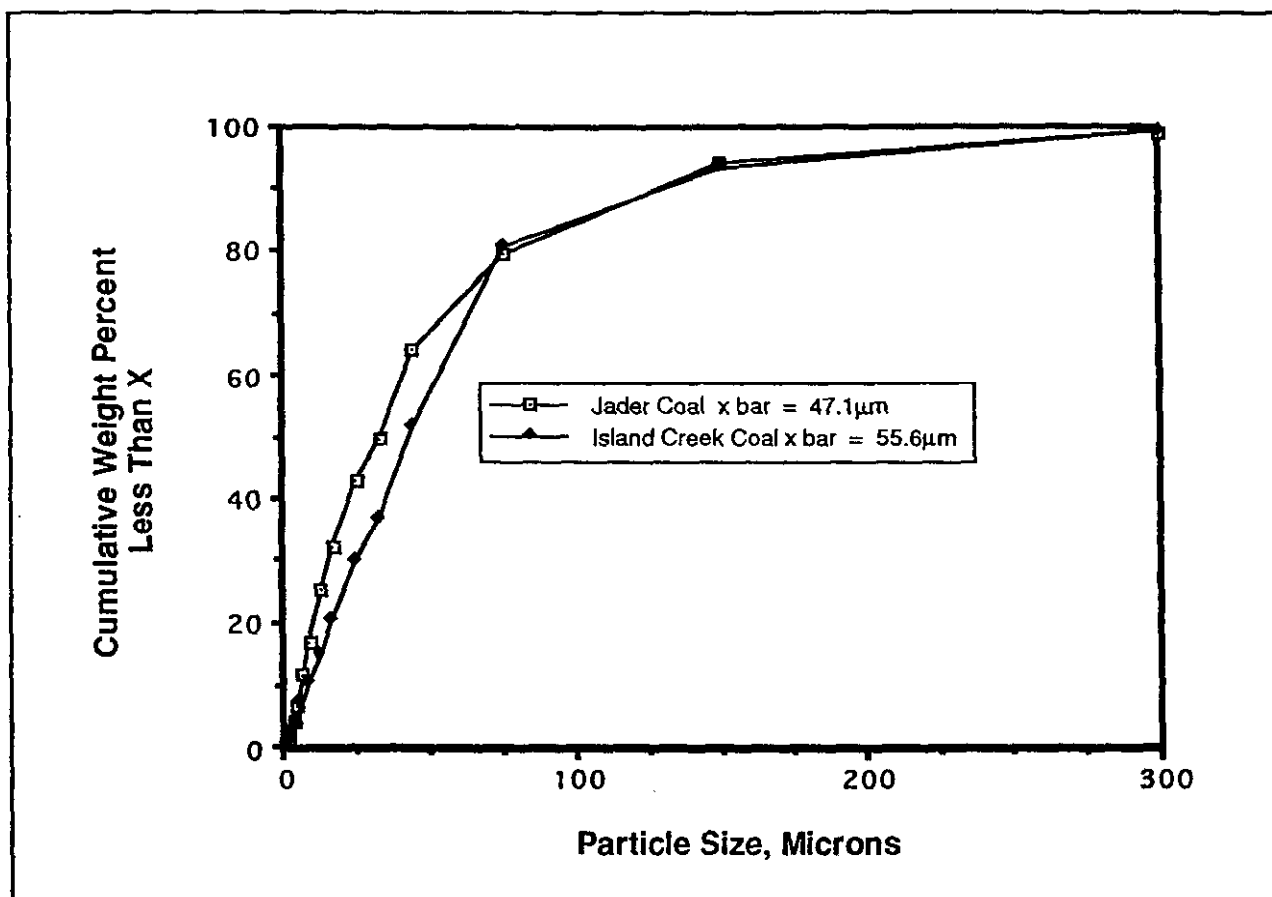


Figure 2.1 Coal Particle Size Distributions For Watson Coals

Test Conditions

Based upon knowledge of the Watson unit and coal analyses, an initial boiler operating condition was established for firing in the FPTF. Based on the results of the initial test for each particular fuel in the FPTF, the conditions for the next test were changed until the maximum temperature and thermal input allowable for controllable deposit removal in both the lower and upper furnace regions of the FPTF could be determined. The tests used to determine these limits make up the test matrix. In this way, the test matrix was used to evaluate the fuel parameters which would lead to the

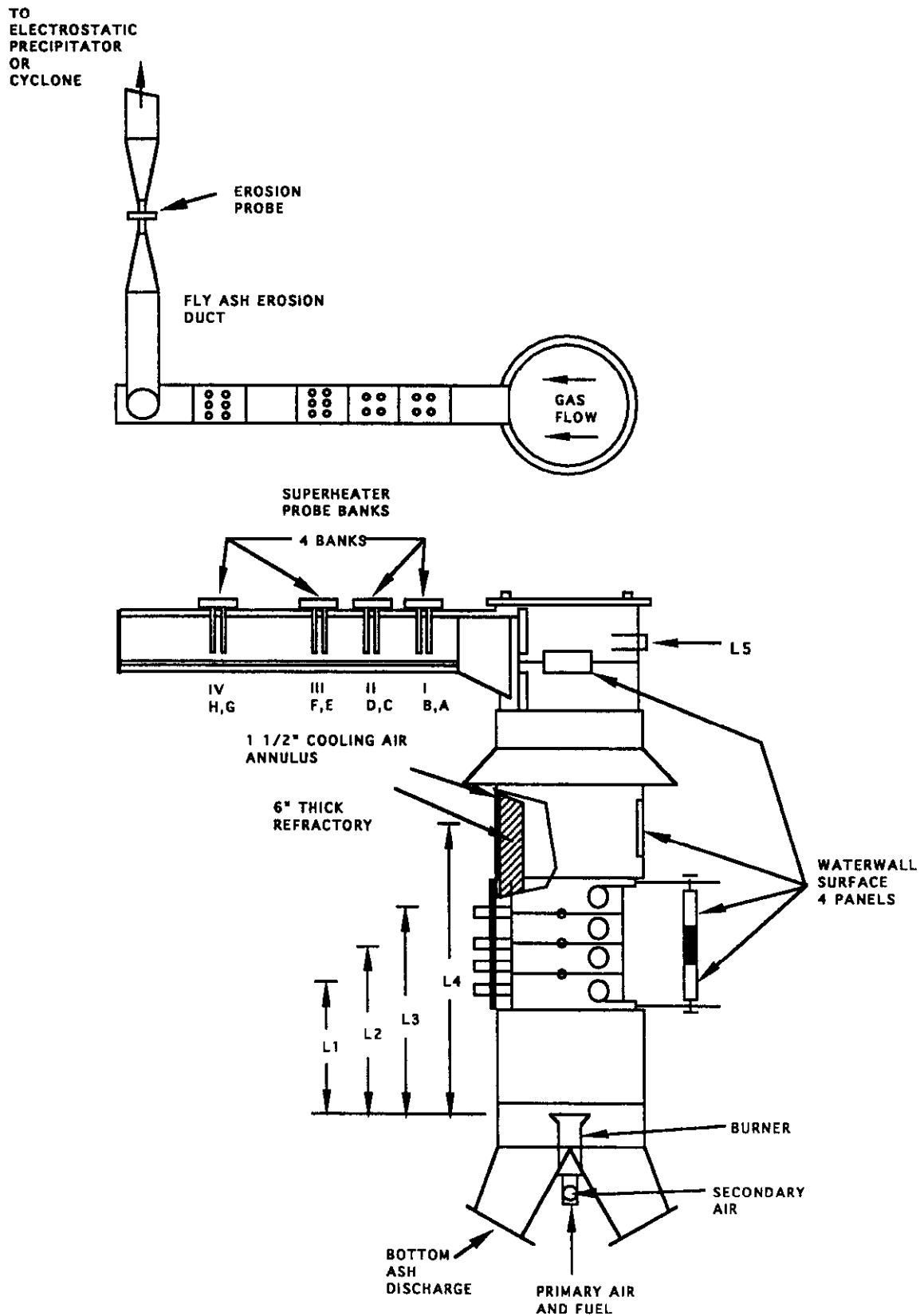


Figure 2.2
Fireside Performance Test Facility

establishment of load-limiting firing conditions in full-scale utility boiler applications.

Table 2.4 shows the test matrix for the Jader and Island Creek coals. Firing rates between 3.2 and 3.8 MBtu/hr and 3.6 and 4.0 MBtu/hr were used to determine the critical conditions at 10% and 20% excess air for the Island Creek and Jader coals, respectively. Flame temperatures corresponding to each firing rate were controlled using secondary air preheat. The first four tests for each particular coal in the test matrix were used to establish critical conditions at 20% excess air and the last four tests were for evaluations at different excess air levels.

Table 2.4 Test Matrix For Watson Coals

Test #	Duration (Hrs)	Firing Rate (MBtu/hr)	Avg. Operating* Gas Temperature (°F)	Excess Air (%)
Island Creek				
1	12	3.6	2900-2925	20
2	12	3.8	2950-2975	20
3	12	3.5	2875-2900	20
4	12	3.6	2900-2925	20
5	12	3.6	2900-2925	10
6	12	3.4	2850-2875	10
7	12	3.2	2800-2825	10
8	12	3.6	2900-2925	30
Jader				
1	12	3.6	2900-2925	20
2	12	3.8	2950-2975	20
3	12	4.0	2875-2900	20
4	10	4.0	2900-2925	20
5	12	4.0	2900-2925	10
6	12	4.0	2850-2875	10
7	12	3.8	2800-2825	10
8	12	3.6	2900-2925	10

* Target temperature, adjacent to Panel P1

Figure 2.3 presents typical FPTF gas temperatures, as a function of distance from the burner, for the four tests fired at the 3.6 MBtu/hr load. Temperatures were measured with shielded, high velocity suction pyrometers at the first eight furnace locations, and the ninth was measured with a bare thermocouple located where the isokinetic dust sample is located. Figure 2.4 depicts typical radial and axial gas temperatures at the four panel elevations in the FPTF. The radial temperatures at each level show the relative uniformity of temperature at each level. Radial variations in temperature which did occur may be attributed to irregularities in flame shape and to turbulence in the gas flow.

In order to better simulate behavior and reduce questionable extrapolations it is necessary to closely match key conditions in the pilot-scale test unit to those of the field unit. The time-temperature history of the coal mineral matter/ash prior to deposition and the local furnace heat flux that the ash is exposed to after depositing are believed to be the most important parameters influencing deposits' characteristics. One of the few direct comparisons that can be used is localized total heat flux. Figure 2.5 shows the heat fluxes measured in the Watson Unit No. 4 compared to equivalent levels in the FPTF. Good agreement is seen between the field and the FPTF at similar times (positions) in the combustion process. Total heat flux was measured with the same water-cooled total heat flux meter in both locations.

Residence time of the bulk gas as a function of distance from the burner was calculated from a bulk flow mass-energy balance. Figure 2.6 illustrates this relationship for the two test fuels at two stoichiometries at identical loads. Both the residence times and temperatures were controlled such that, when tested at similar thermal loads, the tests at similar stoichiometries had very similar time-temperature histories. Complete residence time data for each test run can be found in the appendix.

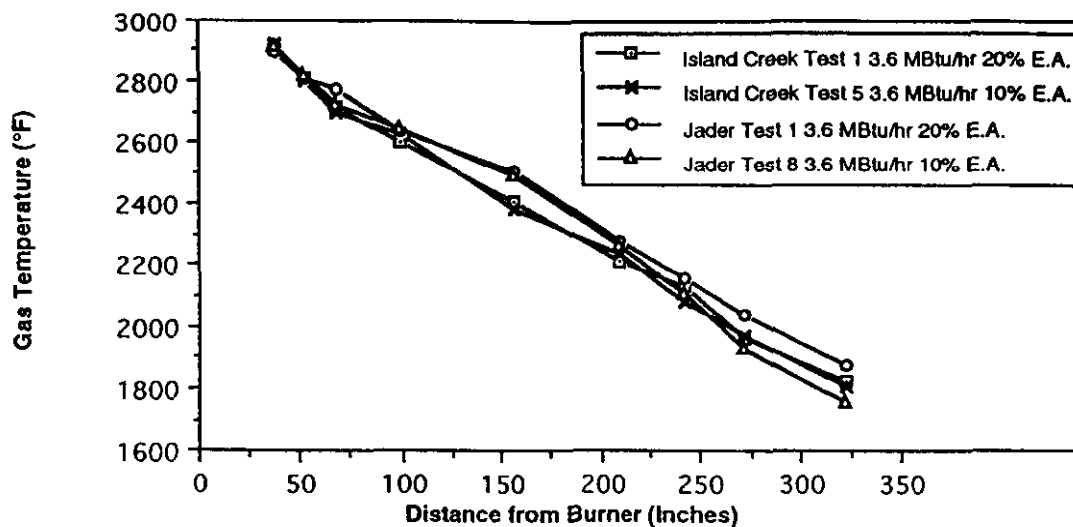


Figure 2.3 Typical FPTF Variation of Temperature Profiles with Distance During Test Firing of Watson Fuels

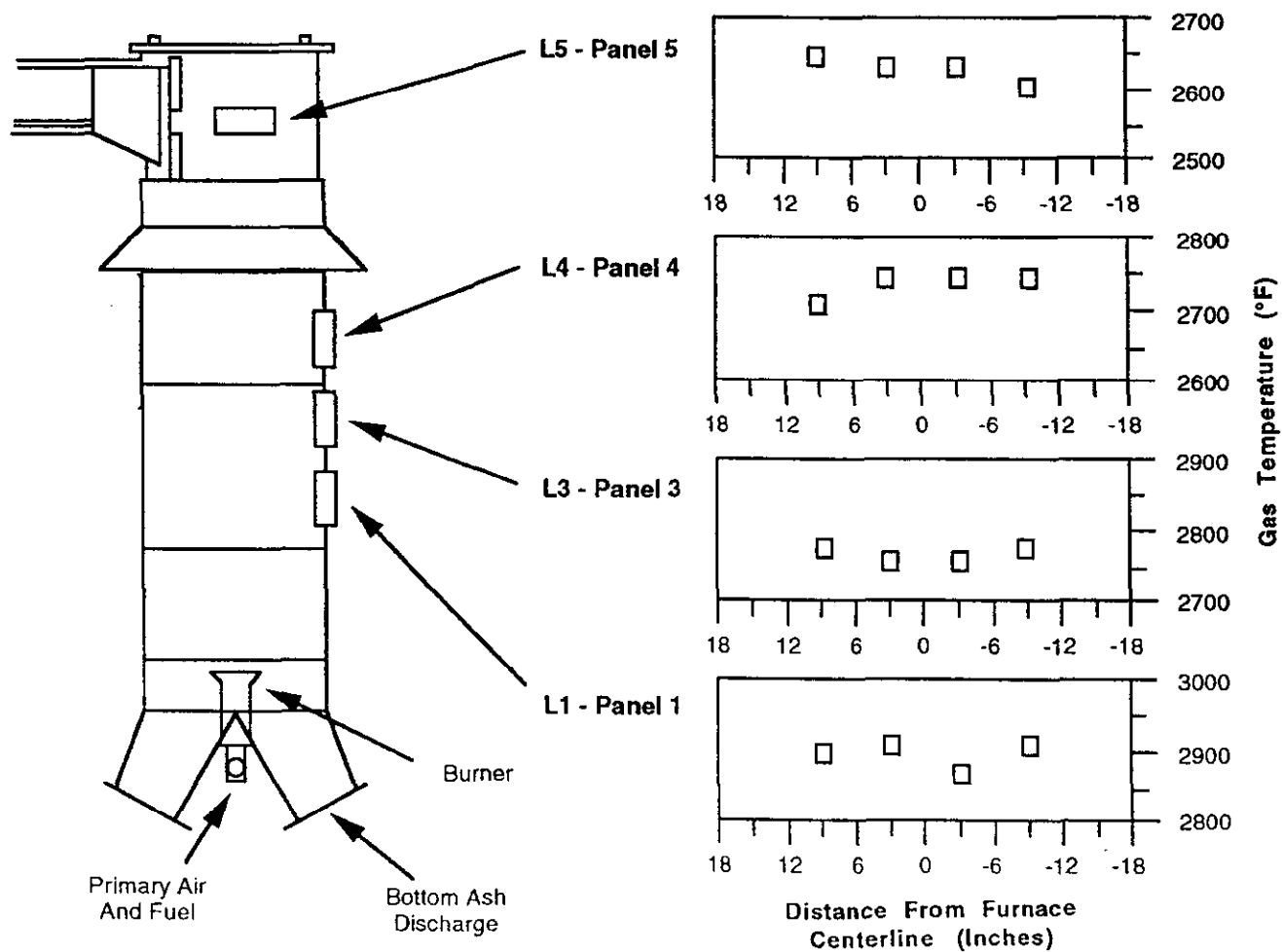


Figure 2.4 Typical Radial and Axial Gas Temperature in the FPTF While Firing Watson Fuels

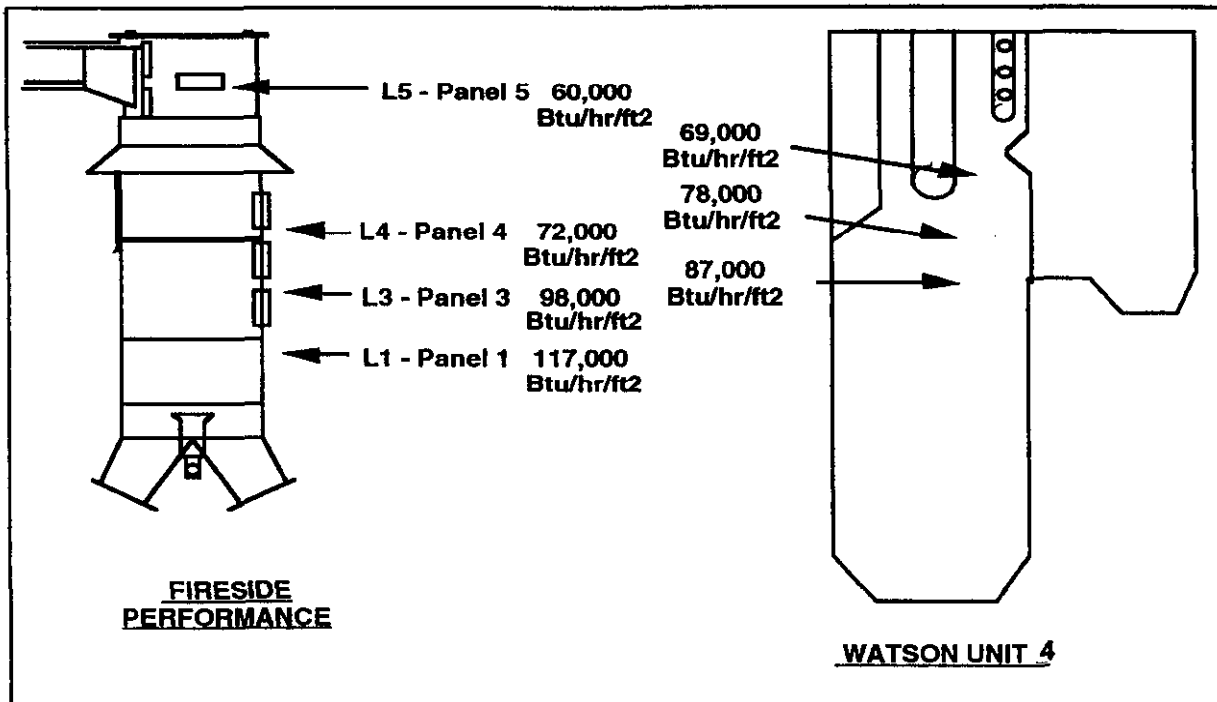


Figure 2.5 Heat Flux Comparison Between the FPTF and Watson Unit 4

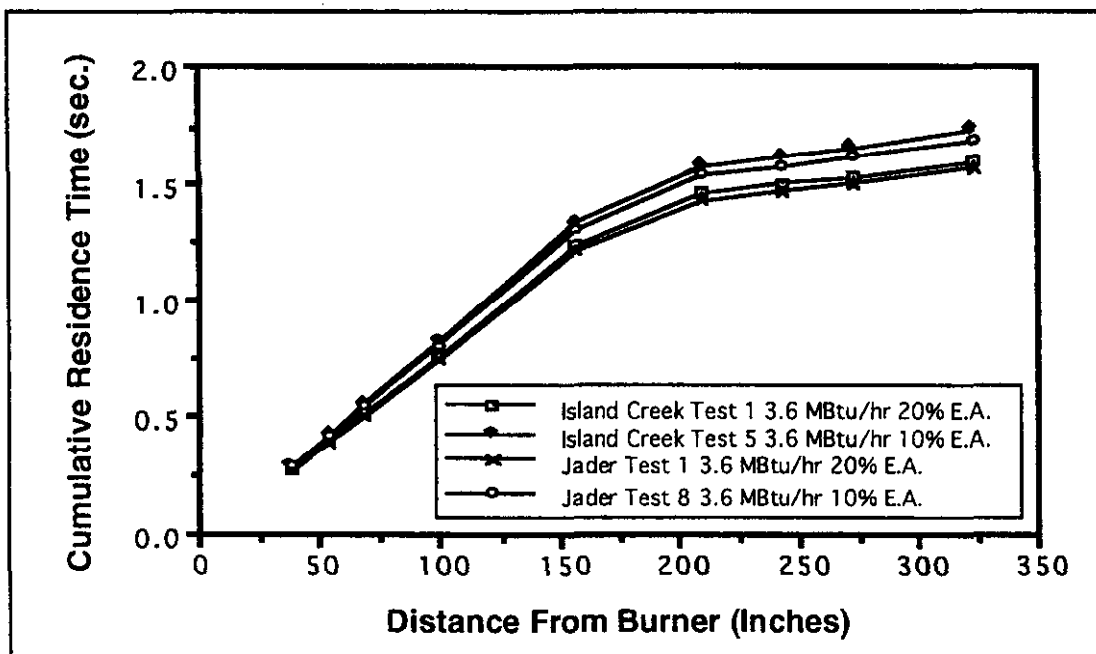


Figure 2.6 Comparison of Bulk Residence Times at Similar Loads for Watson Coals

Furnace Slagging

Furnace slagging characteristics on the simulated waterwall surfaces in the FPTF are determined by three factors; relative deposit removability (response to soot blowing), effect of the deposit on heat transfer, and physical appearance and thickness of the deposit.

Simulated Waterwall Deposits

As shown previously in Figure 2.2, simulated waterwall panels have been mounted flush with the refractory wall fireside surface. At the different elevations in the FPTF, each panel has a 15" x 15" surface (ribbed to model a boiler waterwall tube surface as shown in Figure 2.7). The panels in the lower sections of the FPTF are surrounded by a water cooled frame to reduce interference from slag generated on adjacent hot

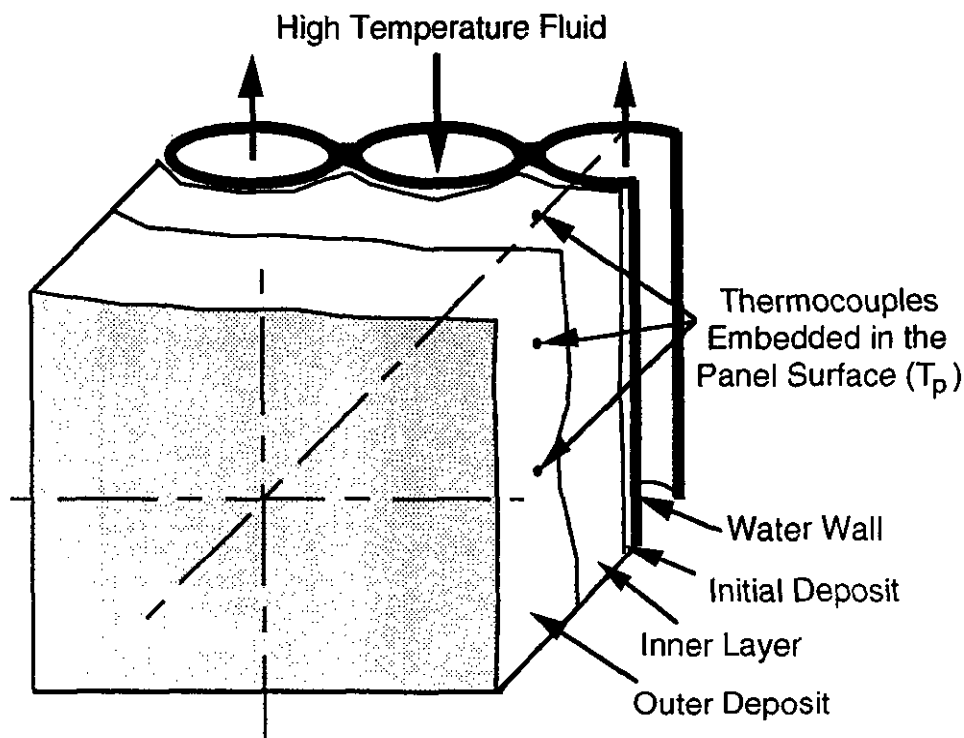


Figure 2.7 Schematic of Waterwall Panel and Deposit

refractory surfaces. Fireside panel surface temperatures are controlled through heat exchangers, using Syltherm, a high boiling point organic liquid, to extract the heat

required to maintain a s
continuously monitored
temperature increase fro

Deposit removability is r
surfaces. Panel P1 is g
hottest point in the FP
necessary for the depc

Figures 2.8 to 2.10 show the heat flux recoveries for the Island Creek and Jader coals at 20% and 10% excess air and the various furnace loads (heat inputs) used to determine the critical conditions for each coal at the two excess air levels. For comparison purposes between different loads, coals and excess air levels the initial heat flux is set equal to 100% in each case and the decrease in heat flux and the heat flux recovery are determined based upon the initial heat flux. The heat flux recoveries are from Panel P1 only, as it is located adjacent to the hottest section of the FPTF and will be subjected to the most severe conditions. The various furnace loads tested for each coal are used to bracket the critical conditions as closely as possible. The results clearly demonstrate that the Jader coal could be fired at a higher thermal load and temperature than the Island Creek coal at both 20% and 10% excess air and still result in cleanable deposits. These results agree well with observed field performance. The field results show that when firing the Island Creek coal at the Watson unit the increased wall slagging resulted in an increased FOT when compared to the Jader coal at similar conditions. FPTF results also show that when firing either the Jader coal or the Island Creek coal running at a reduced excess air level (from 20% to 10%) had a very detrimental effect on furnace slagging (deposit removability). Decreasing the excess air from 20% to 10% necessitated drops in load and temperature from 4.0 Mbtu/hr/3010°F to 3.6 MBtu/hr/2910°F and 3.6 MBtu/hr/2910°F to 3.2 MBtu/hr/2830°F for the Jader and Island Creek coals, respectively, to maintain marginally cleanable waterwall deposits.

For each of the test runs shown in Table 2.4, the heat flux passing through the panel surface was recorded as a function of time and is reported for Panels 1 and 3 in Figures 2.11 to 2.16. Heat flux plots for each of the individual tests show a large drop in the heat transferred through the panels in the first one to four hours of the test. During the initial buildup stages of the deposit formation, a thin powdery layer of deposit was formed on the panel surfaces. The initial steep drop in heat flux can be attributed to two major effects on heat transfer: 1) the powdery initial layer typically has a lower emissivity/absorptivity than that of the iron oxide panel surface, causing more

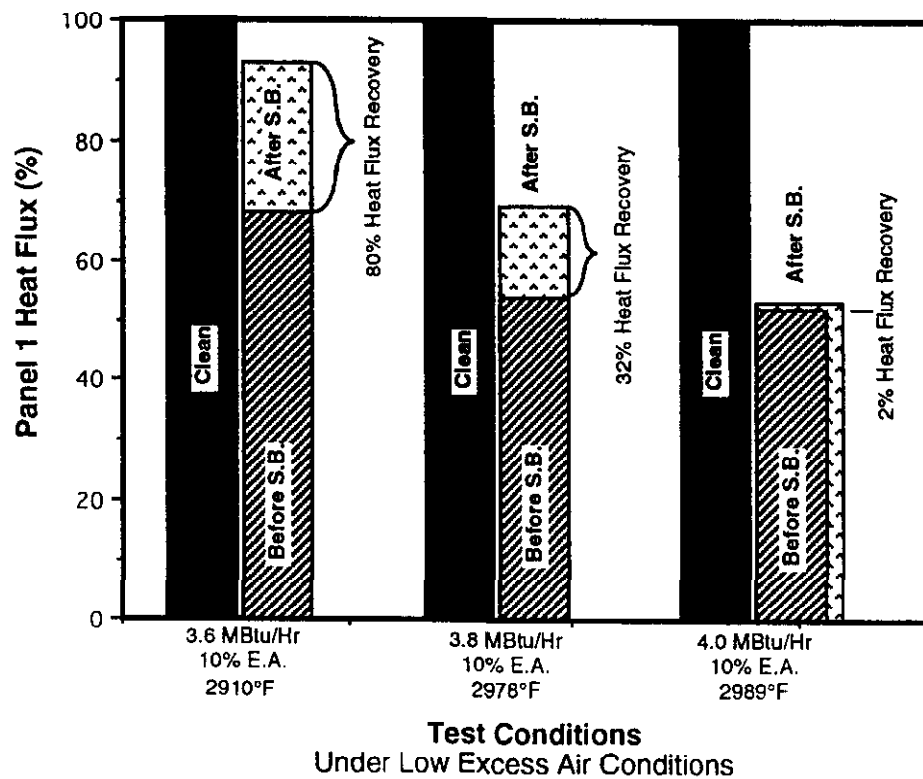
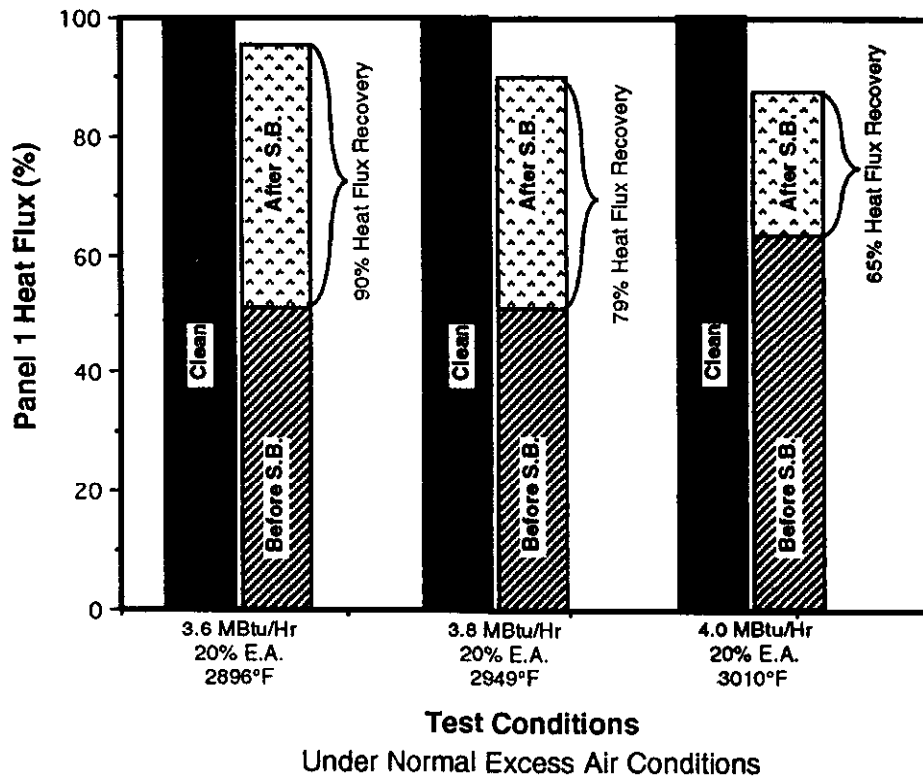


Figure 2.8 Jader Coal Heat Flux Summary

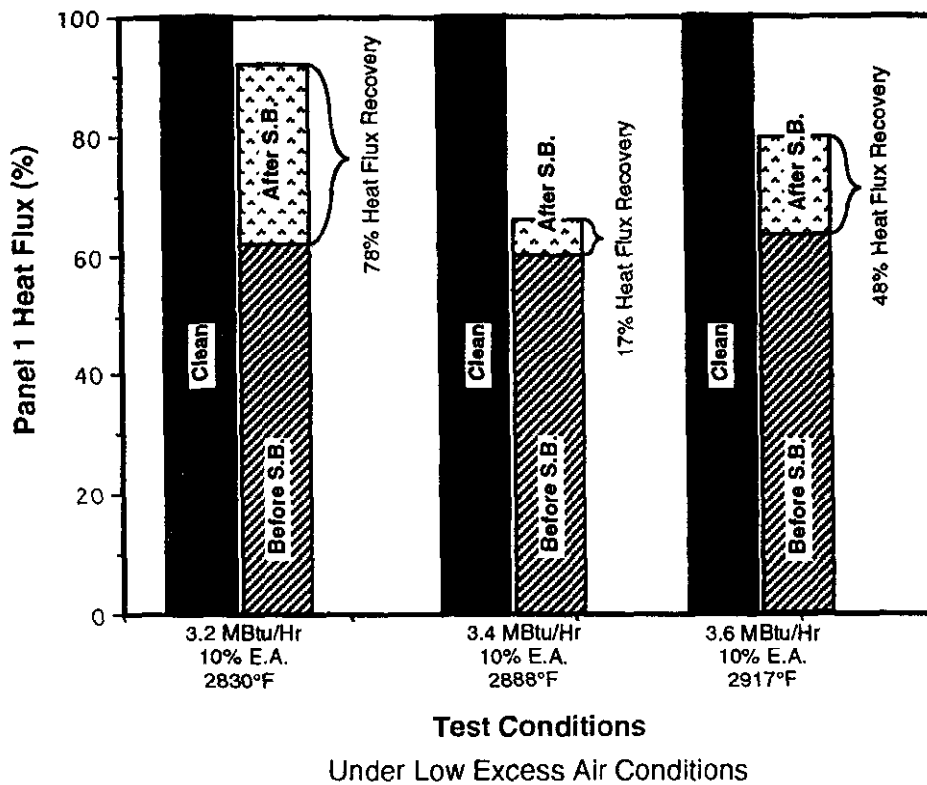
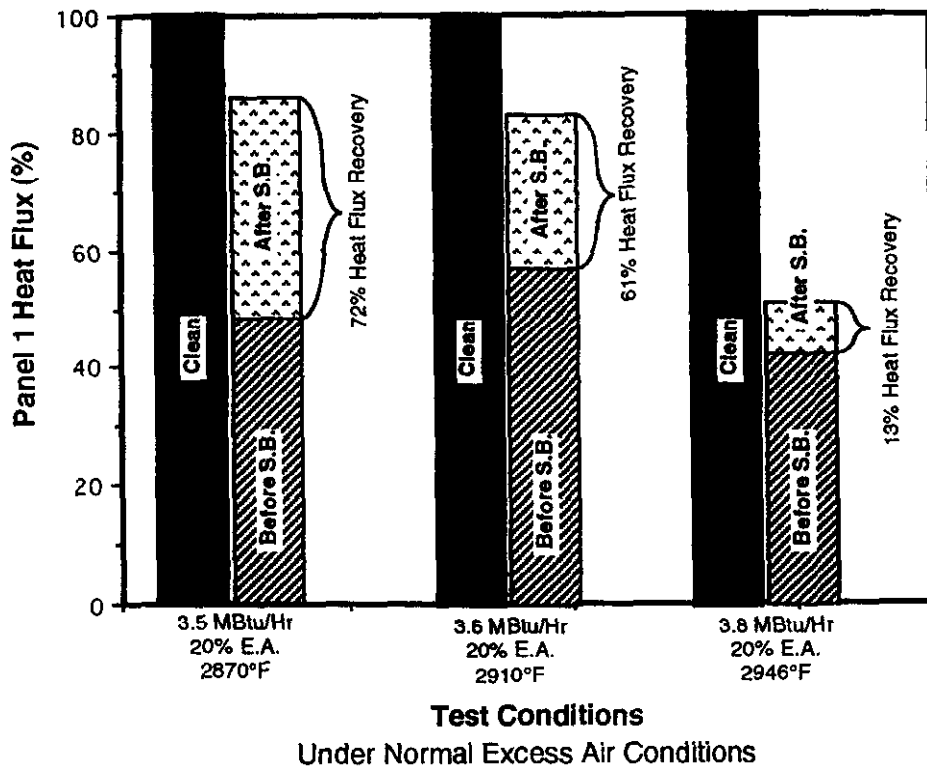


Figure 2.9 Island Creek Coal Heat Flux Summary

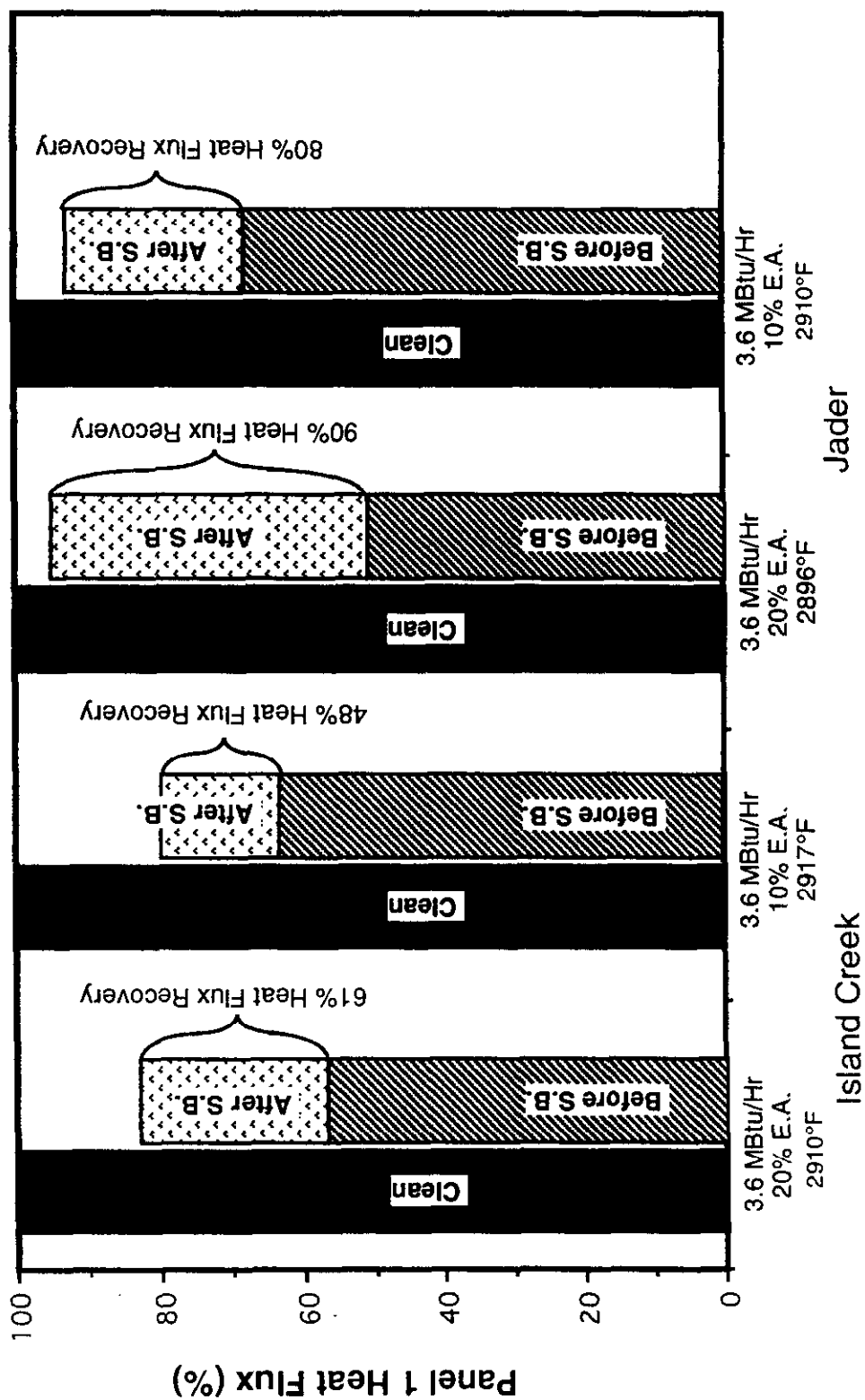


Figure 2.10 Watson Fuel Testing Heat Flux Summary
At Similar Firing Rates

of the incident radiation to be reradiated, and 2) inter-particle bonds which form the initial deposition layer act as a thin, insulative layer which limits conduction from the outermost (fireside) exposed surface to the metal panel surface increasing the deposit outer layer surface temperature.

Decreases in heat flux through the panel during the initial buildup period (the first few hours, during which time the clean panel surface develops a powdery inner deposit layer) were much more dramatic from hour to hour than after that initial buildup period. As lower furnace deposits continue to grow, changes in deposit emissivity and thermal conductivity diminish. However, significant changes in deposit thermal properties (radiative and conductive) occur as deposits transform from a powdery state into a sintered state and then into a molten state. Typically, deposits initially form as sintered particle agglomerations in the depressions between the ribbed convex tube surfaces of the simulated waterwall panels. As the deposits grow and protrude further into the furnace, they are exposed to higher temperatures and develop a “sticky” or tacky surface. Impacting particles are retained on this surface, and the deposits grow out of the webs to cover the tube surfaces as well. As the deposits continue to accumulate, the surface may be partially or completely transformed to a molten state. Molten deposits, if temperatures are sufficiently high, could run down the crown of the tubes, since once the panel has developed a coating of deposits, these are the hottest areas on the panel. Generally, the panels in the higher temperature furnace zones are the first to develop molten deposits, and exhibit the most pronounced slagging.

Figures 2.11 to 2.16 illustrate that for most of the test runs, a thermodynamic equilibrium has been achieved between the combustion heat released and the heat absorption through the panel. This steady state condition is reached when panel deposit thermal characteristics are no longer significantly changing with time. For example, once the deposit outer layer becomes molten, additional deposition runs off the panel onto the furnace walls. When lower furnace deposits are formed which do not have a molten exterior, this thermodynamic equilibrium can be reached when the

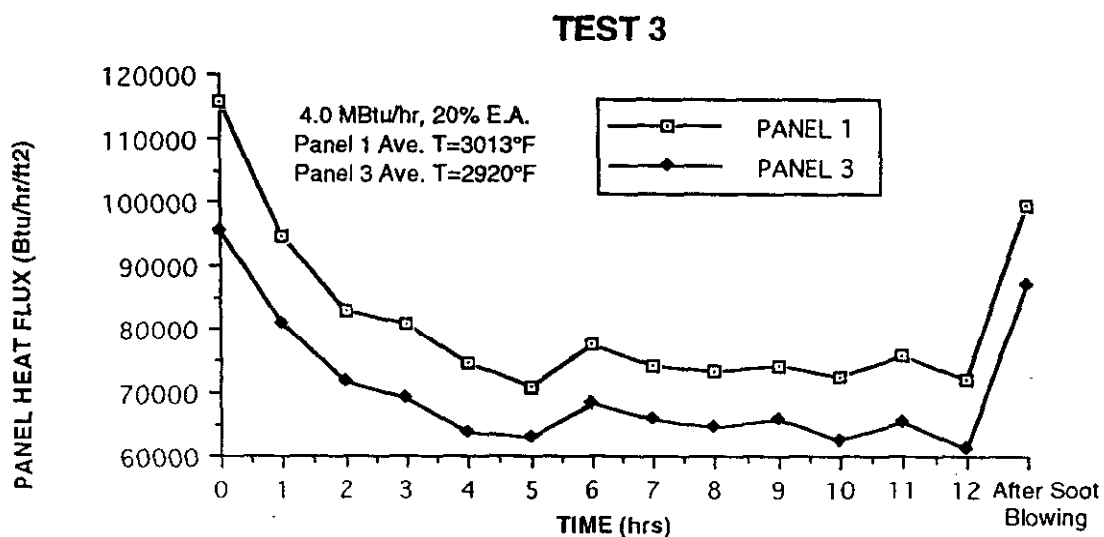
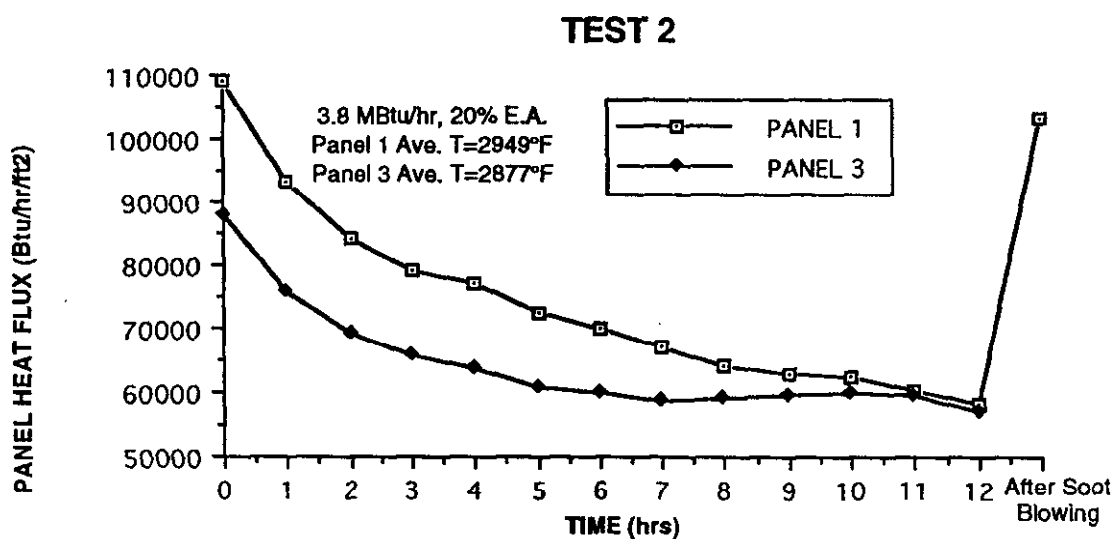
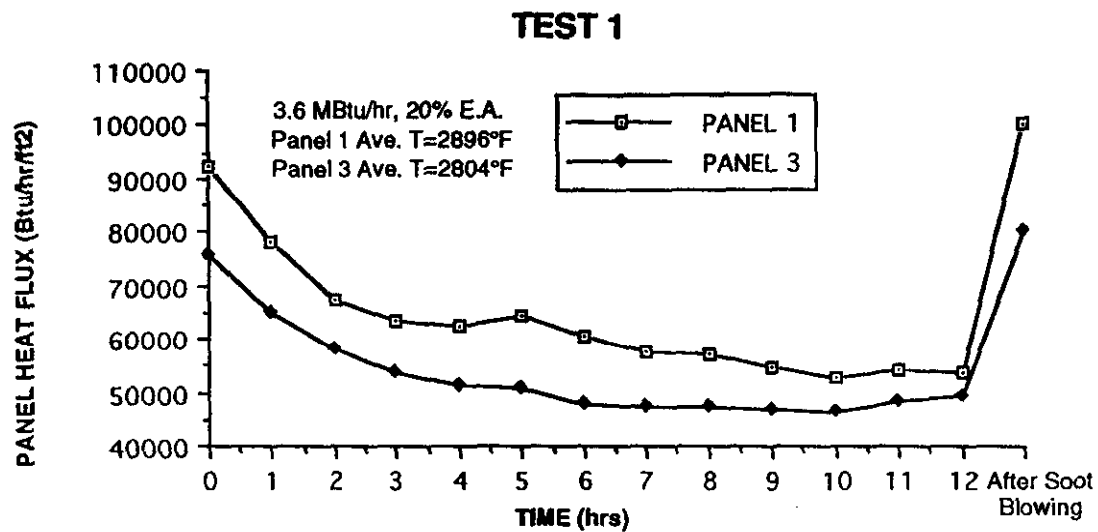
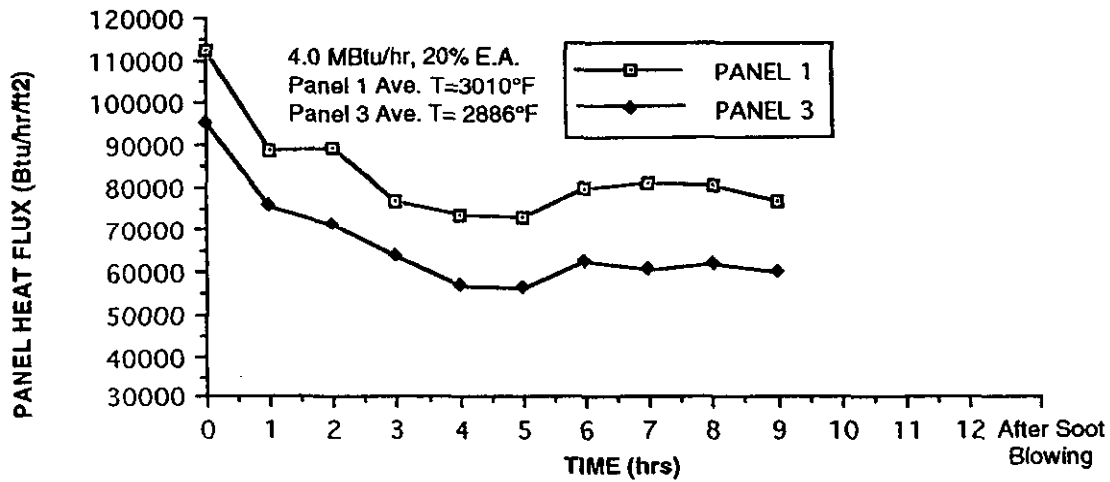
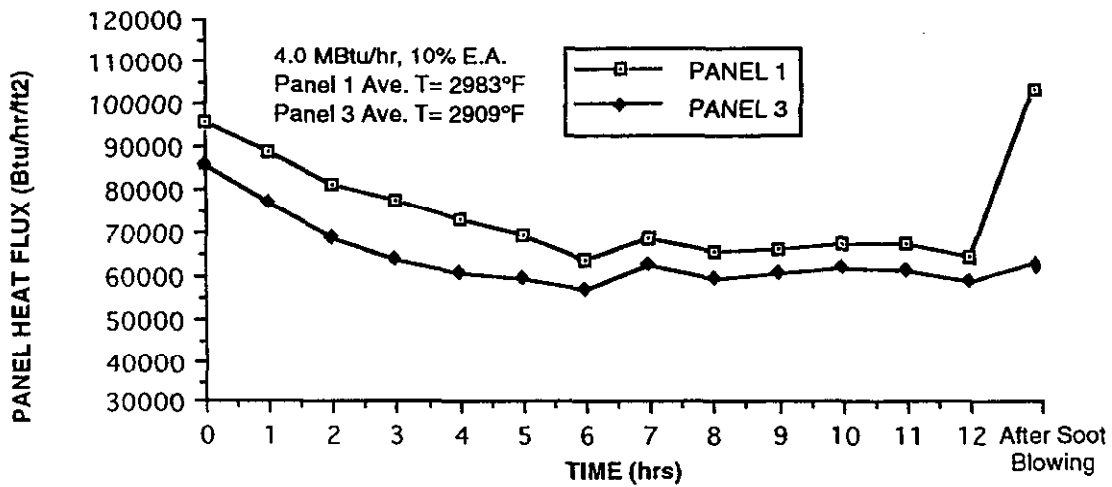


Figure 2.11 FPTF Waterwall Panel Heat Flux While Testing Jader Coal

TEST 4



TEST 5



TEST 6

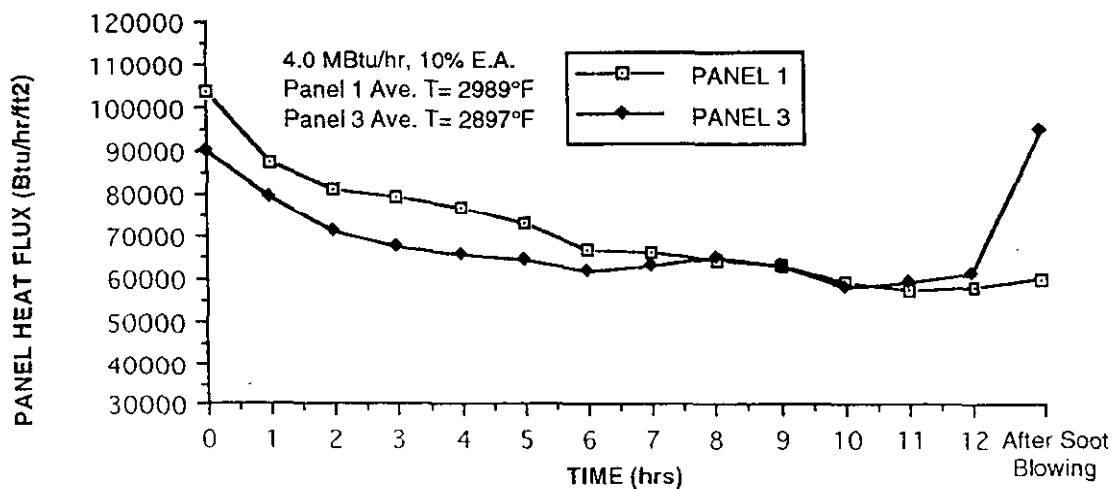
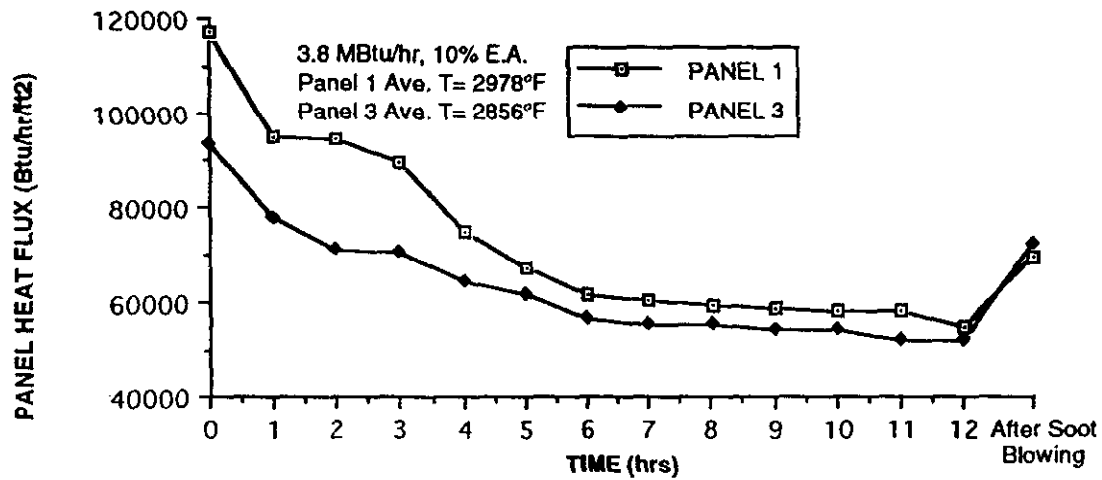


Figure 2.12 FPTF Waterwall Panel Heat Flux While Testing Jader Coal

TEST 7



TEST 8

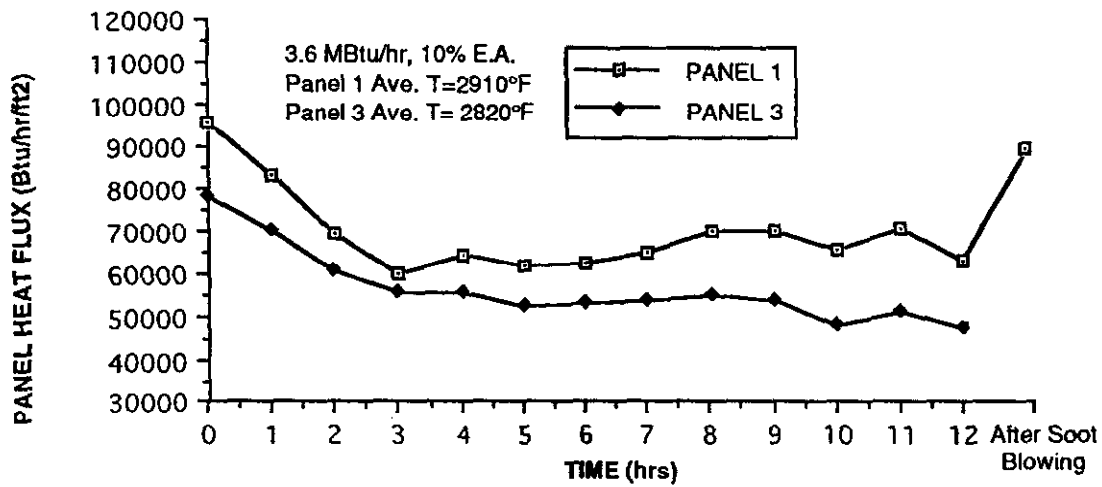
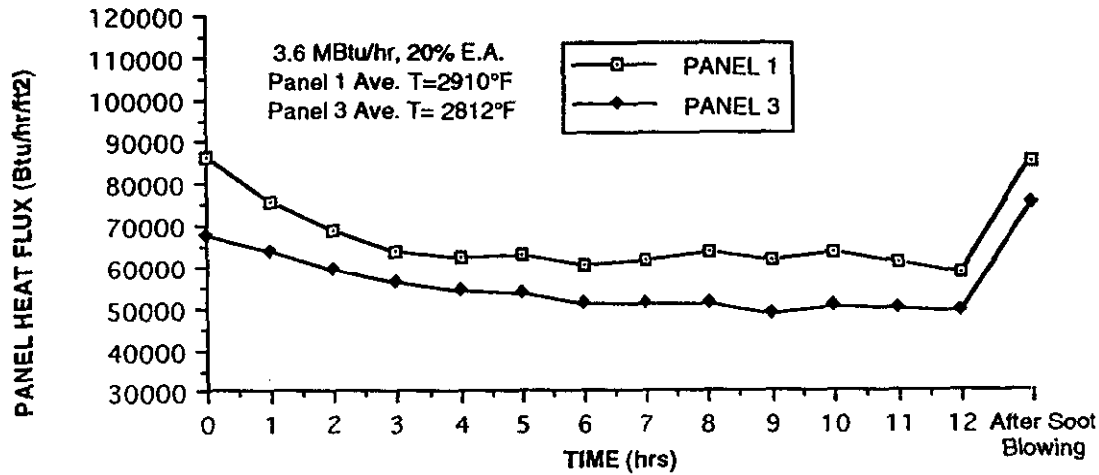
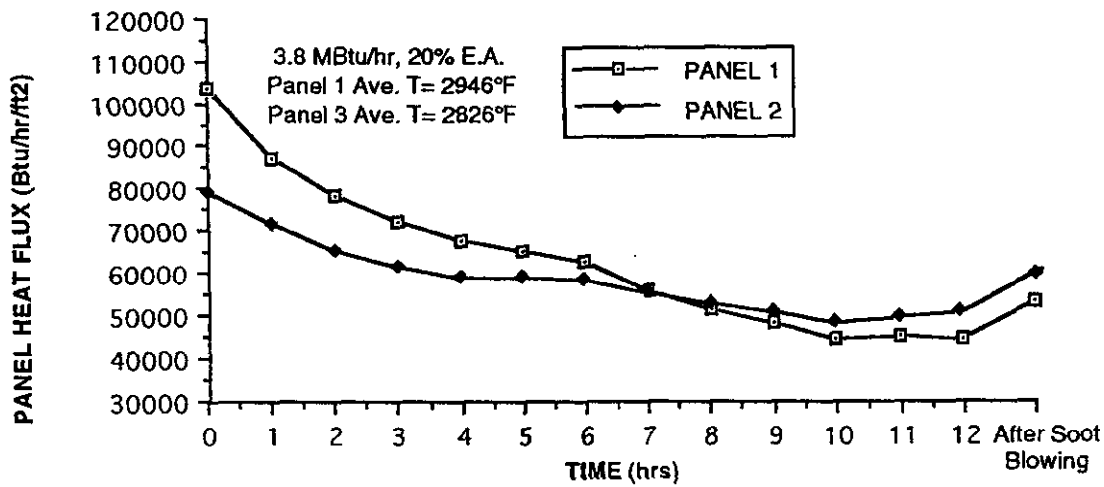


Figure 2.13 FPTF Waterwall Panel Heat Flux While Testing Jader Coal

TEST 1



TEST 2



TEST 3

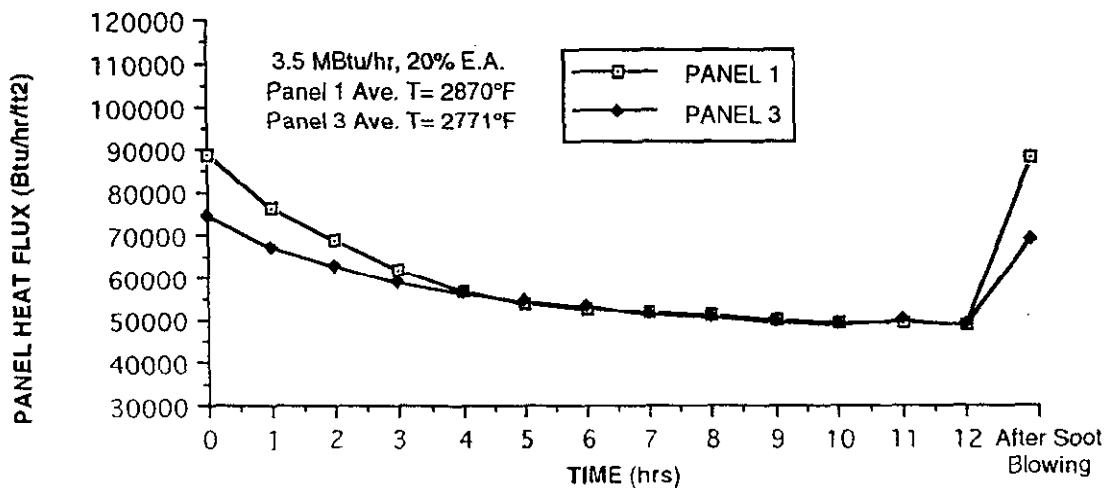
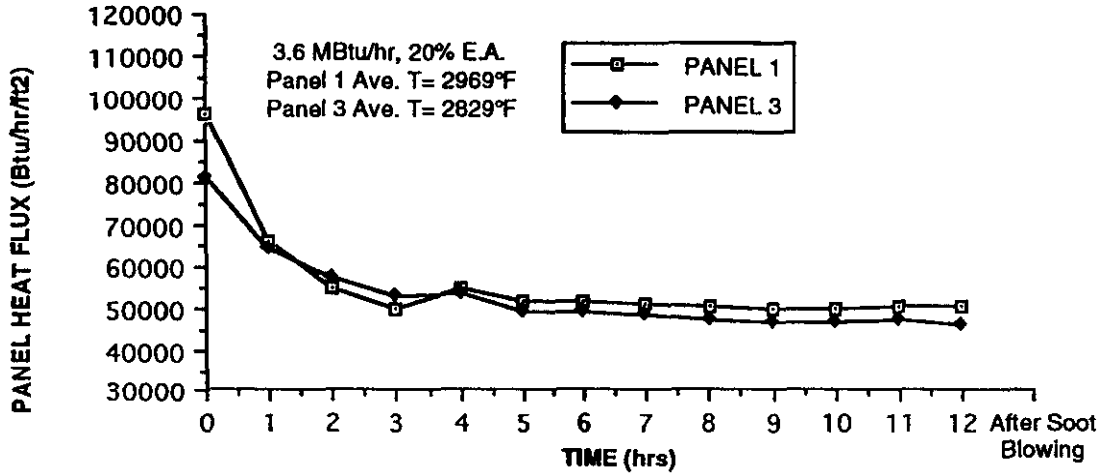
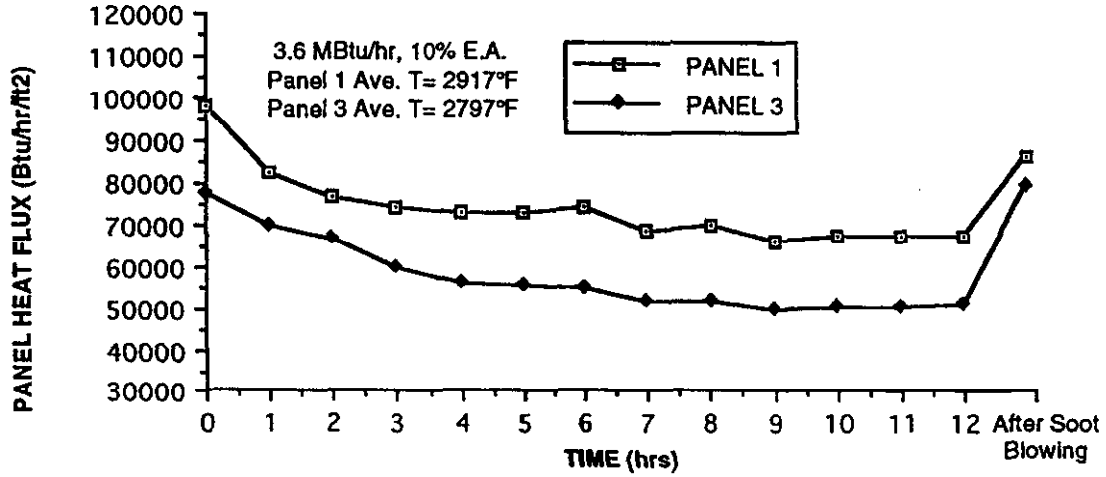


Figure 2.14 FPTF Waterwall Panel Heat Flux While Testing Island Creek Coal

TEST 4



TEST 5



TEST 6

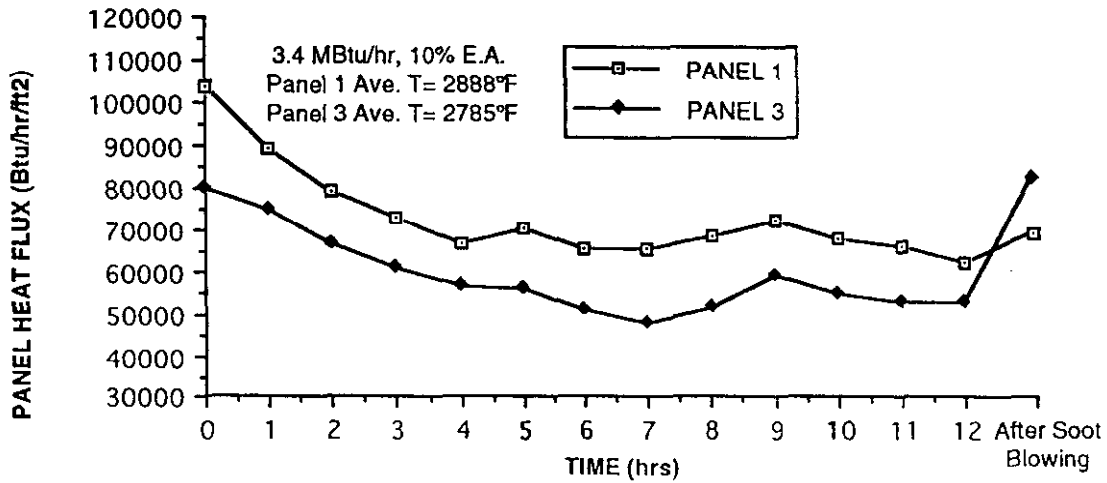
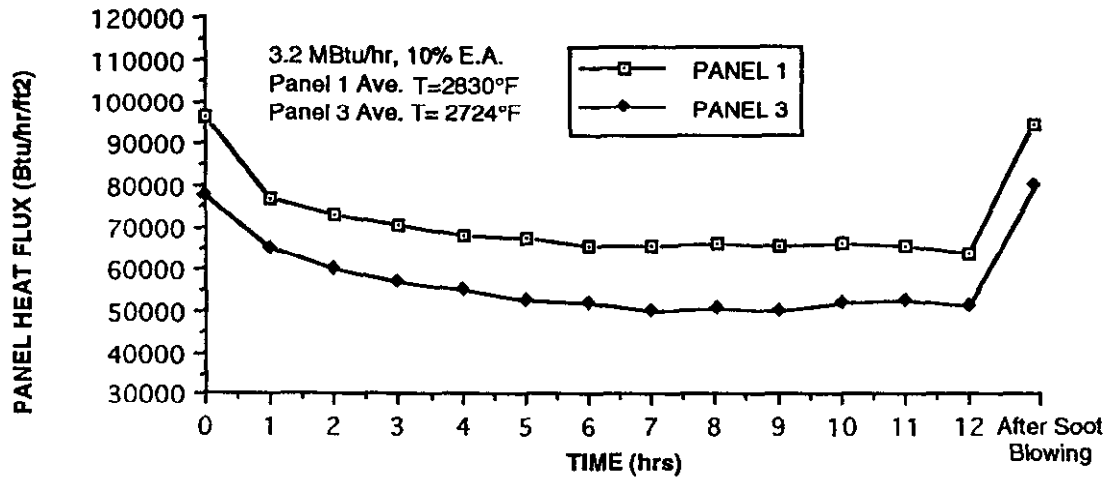


Figure 2.15 FPF Waterwall Panel Heat Flux While Testing Island Creek Coal

TEST 7



TEST 8

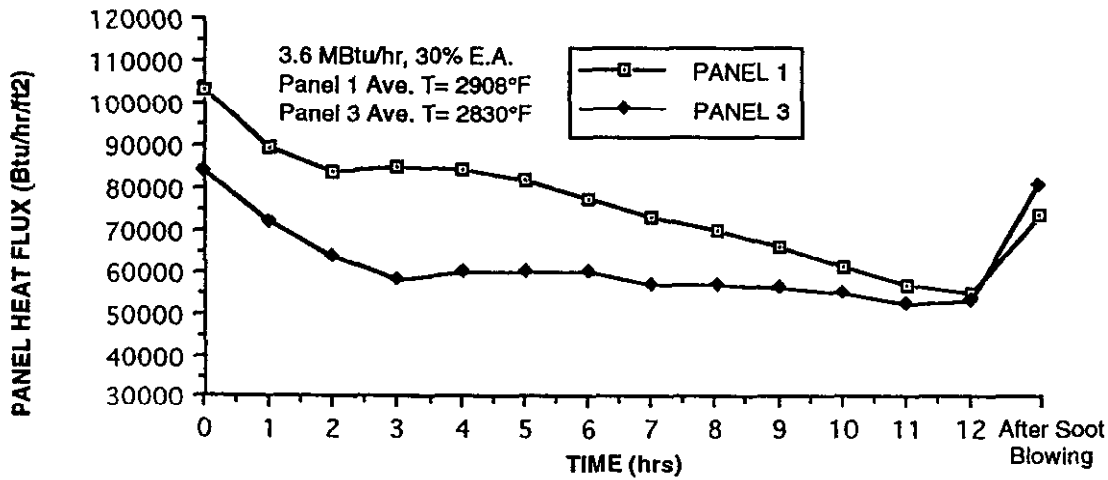
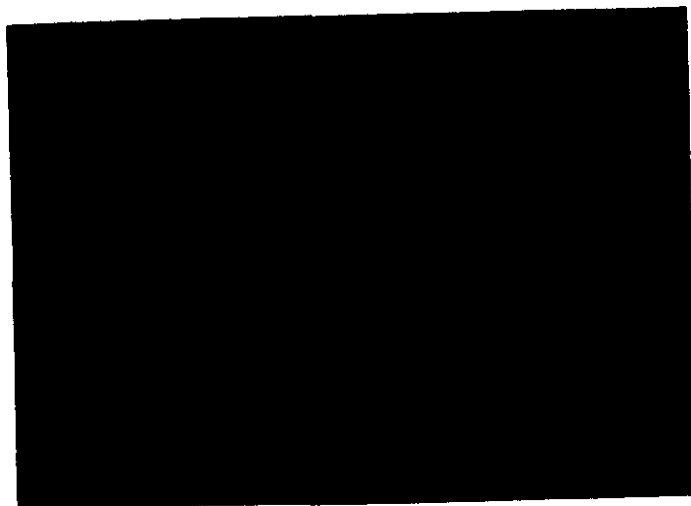


Figure 2.16 FPTF Waterwall Panel Heat Flux While Testing Island Creek Coal

rate of new deposit formation equals the rate at which deposits naturally fall off (slough off) into the furnace because of deposit weight or forces due to aerodynamic flow patterns in the furnace which dislodge the deposits. It should be noted that the plot of Panel 1 heat flux for the Jader Test 5 shows what would appear to be a removable deposit, however, during the on-line sampling prior to sootblowing, sufficient deposit was removed to give the sootblowing air a foothold that enabled it to remove most of the deposit. In Jader Test 6 the conditions from Test 5 were repeated, however, no on-line sampling was not performed prior to sootblowing, this time the deposit was not removable. During all subsequent tests sootblowing was performed before any on-line sampling is performed.

During the twelve hour test runs, the simulated waterwall panels were photographed at regular intervals to document the amount of coverage and physical state of the lower furnace wall deposits. Figures 2.17 to 2.29 present time-sequenced photographs of the deposits on Panel 1 during the tests. The figures include photographs of the panel after soot blowing and provide qualitative visual validation of the heat flux recovery data. Test conditions, including local (adjacent to panel) gas temperatures are provided with each series of photographs. At the 20% excess air conditions for both the Jader and Island Creek coal, the photographs clearly show how the deposits became more molten and denser with increasing thermal load and gas temperatures. At 10% the effect is still apparent but is not as pronounced. A possible explanation why the deposits did not appear to change as much with increasing loads and temperatures at the 10% excess air level could be due to the fact that the deposits were already in a more molten state due to the 10% excess air level. The photographs clearly provide a validation for the heat flux recovery data. The Jader and Island Creek coals could be fired at a maximum of 4.0 MBtu/hr, 3010°F and 20% excess air and 3.6 MBtu/hr, 2910°F and 20% excess air, respectively, and have deposits cleanable by soot blowing. For the 10% excess air case the Jader and Island Creek coals could be fired at 3.6 MBtu/hr and 2910°F, and 3.2 MBtu/hr and 2830°F, respectively, and have cleanable deposits. The photographs also show that as



2 HOURS



4 HOURS



6 HOURS



8 HOURS



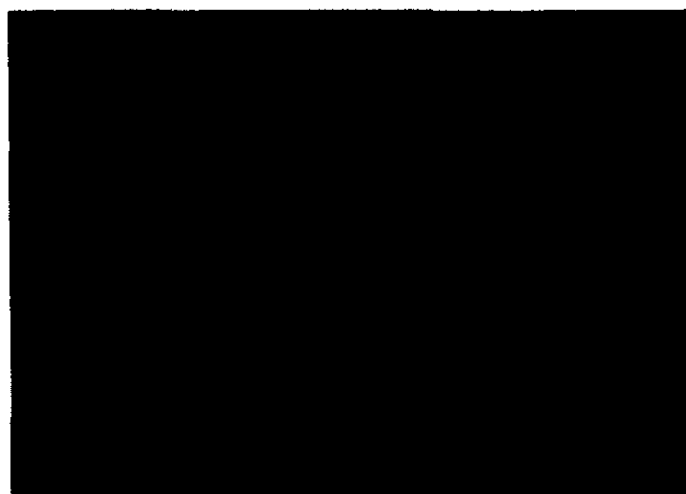
12 HOURS



After Blowing Soot-- 75% Recovery

PANEL 1
JADER-TEST 1
3.6MBtu/hr, 20% E.A., 2896°F

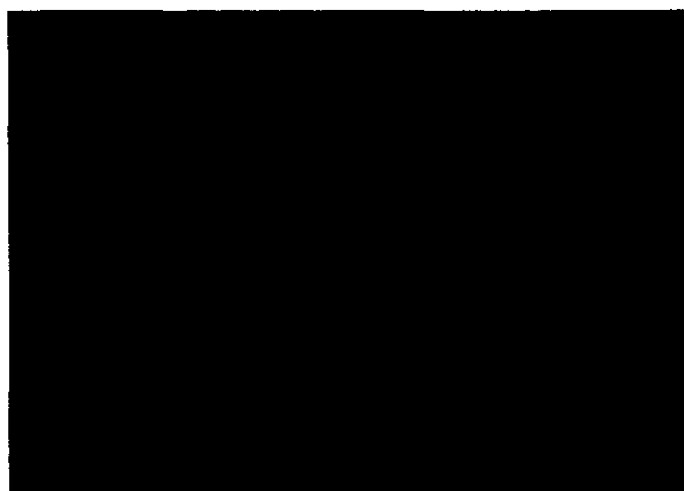
Figure 2.17 Lower Furnace Deposit Buildup-Time Sequencing



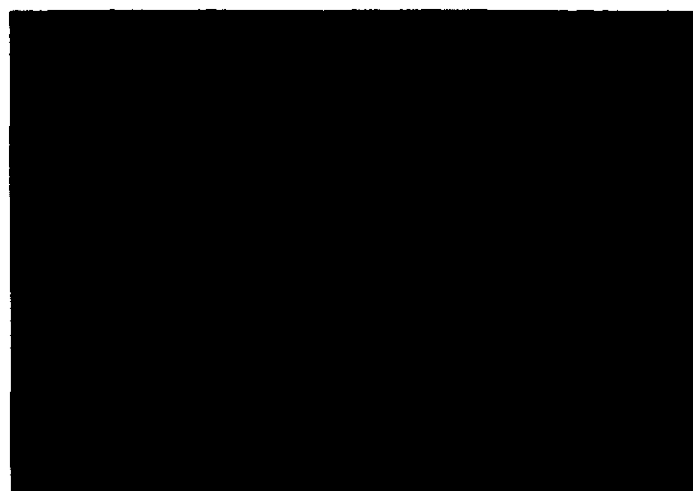
2 HOURS



4 HOURS



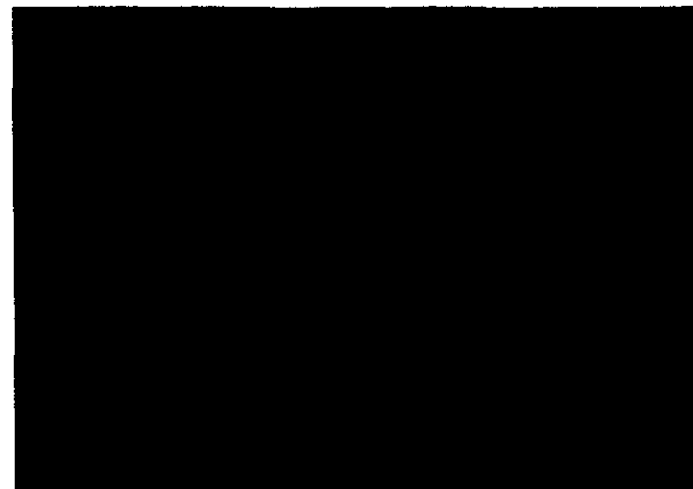
6 HOURS



8 HOURS



12 HOURS



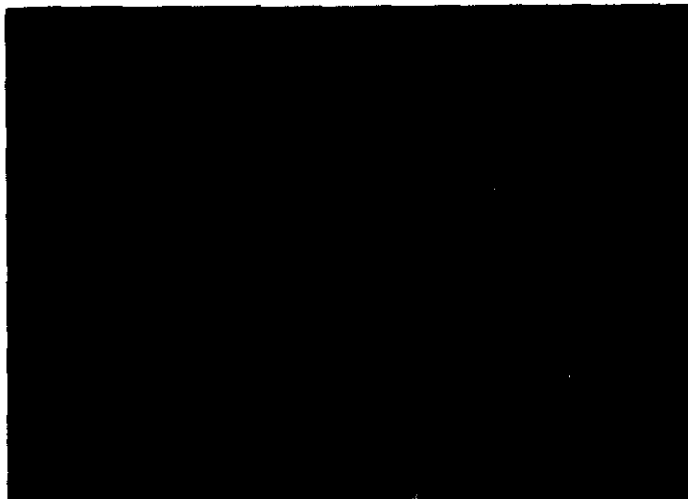
After Blowing Soot-- 79% Recovery

PANEL 1
JADER-TEST 2
3.8MBtu/hr, 20% E.A., 2949°F

Figure 2.18 Lower Furnace Deposit Buildup-Time Sequencing



2 HOURS



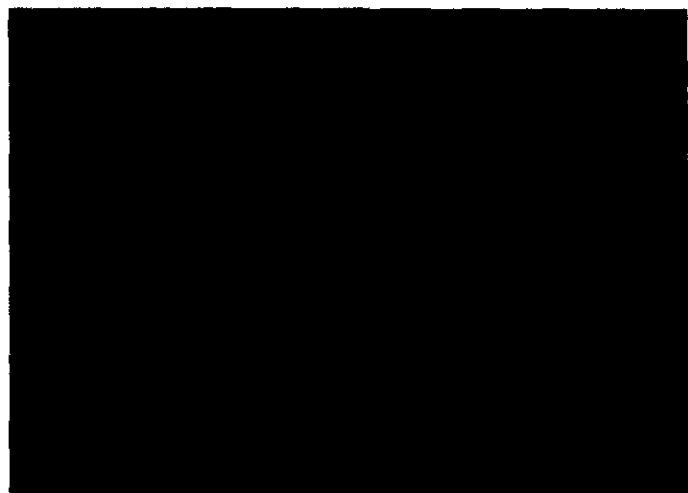
4 HOURS



6 HOURS



8 HOURS



12 HOURS



After Blowing Soot-- 66% Recovery

PANEL 1
JADER-TEST 3
4.0MBtu/hr, 20% E.A., 3013°F

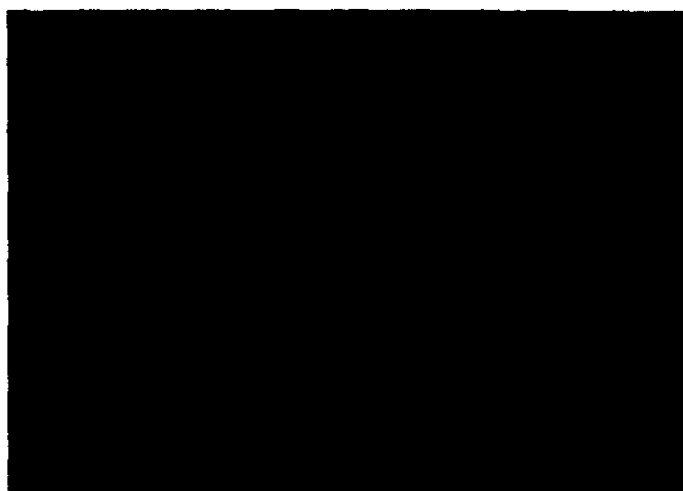
Figure 2.19 Lower Furnace Deposit Buildup-Time Sequencing



2 HOURS



4 HOURS



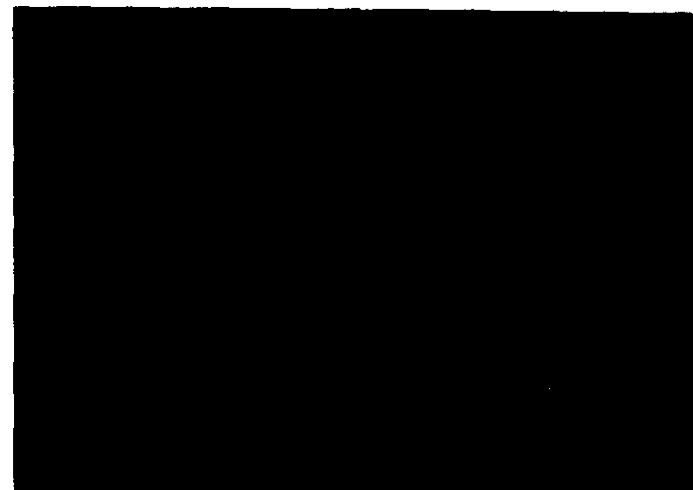
6 HOURS



8 HOURS



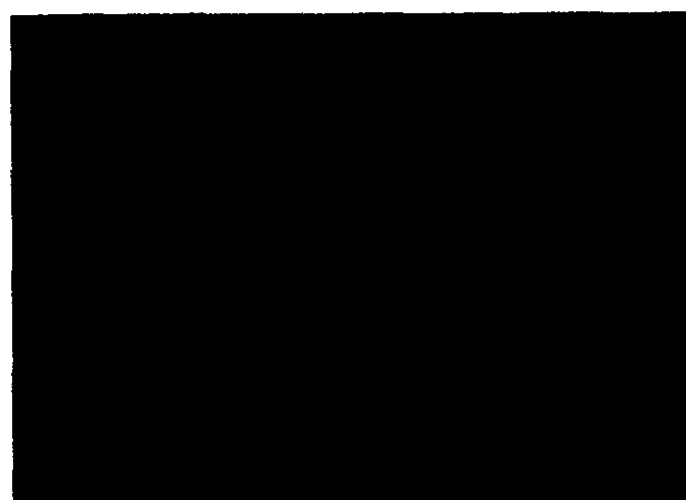
12 HOURS



After Blowing Soot--3% Recovery

PANEL 1
JADER-TEST 6
4.0MBtu/hr, 10% E.A., 2989°F

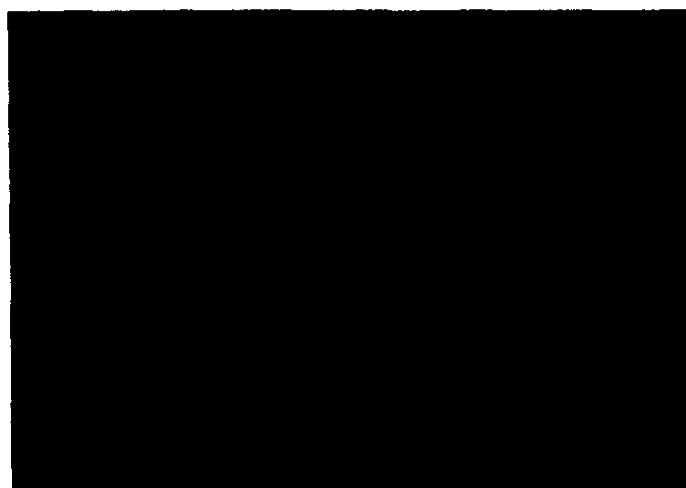
Figure 2.20 Lower Furnace Deposit Buildup-Time Sequencing



2 HOURS



4 HOURS



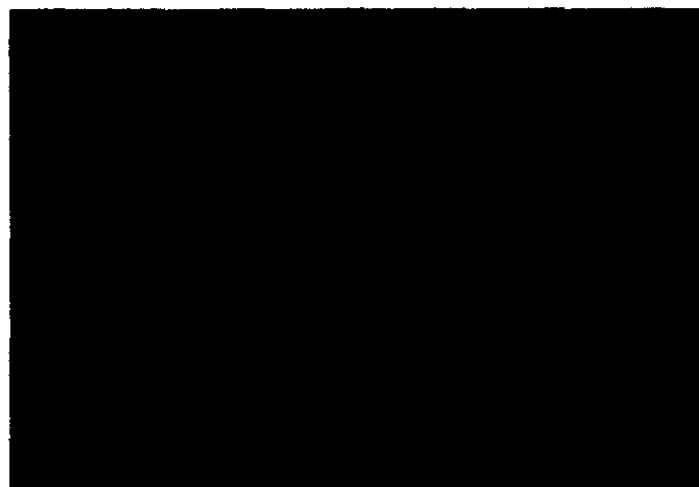
6 HOURS



8 HOURS



12 HOURS



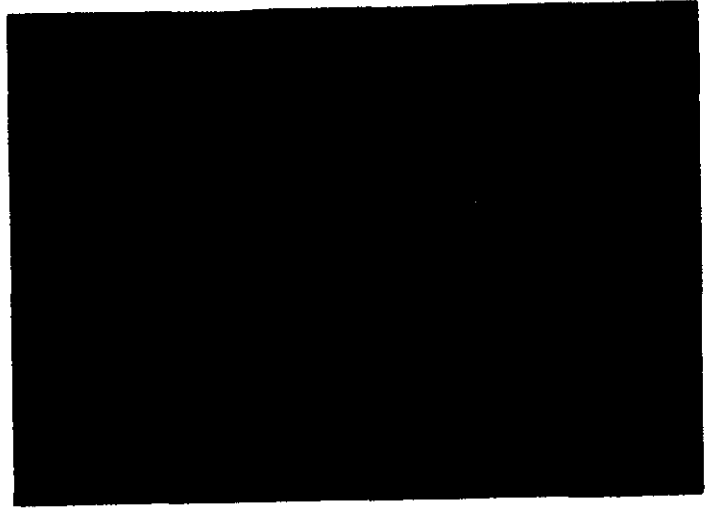
After Blowing Soot--36% Recovery

PANEL 1
JADER-TEST 7
3.8MBtu/hr, 10% E.A., 2978°F

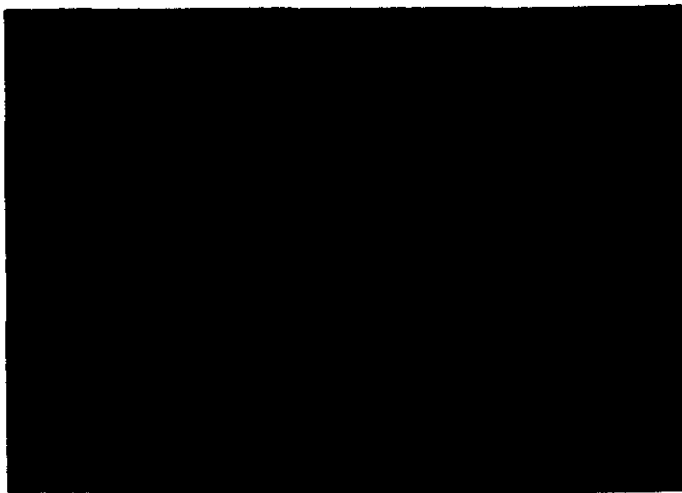
Figure 2.21 Lower Furnace Deposit Buildup-Time Sequencing



2 HOURS



4 HOURS



6 HOURS



8 HOURS



12 HOURS



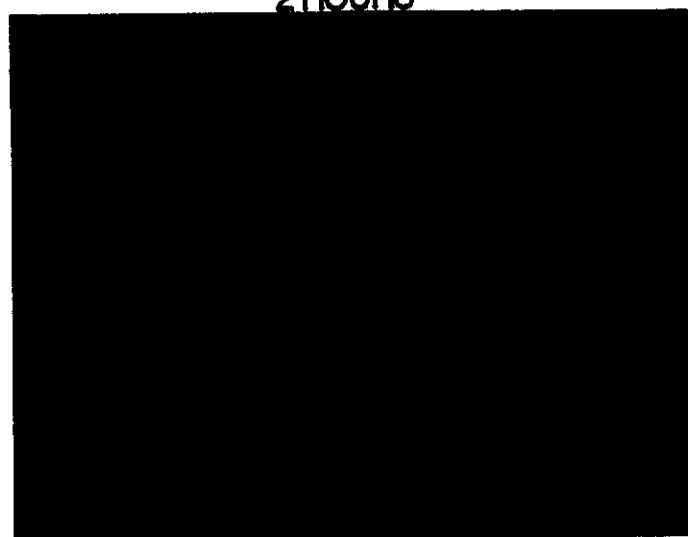
After Blowing Soot--78% Recovery

PANEL 1
JADER-TEST 8
3.6MBtu/hr, 10% E.A., 2912°F

Figure 2.22 Lower Furnace Deposit Buildup-Time Sequencing



2 HOURS



4 HOURS



12 HOURS



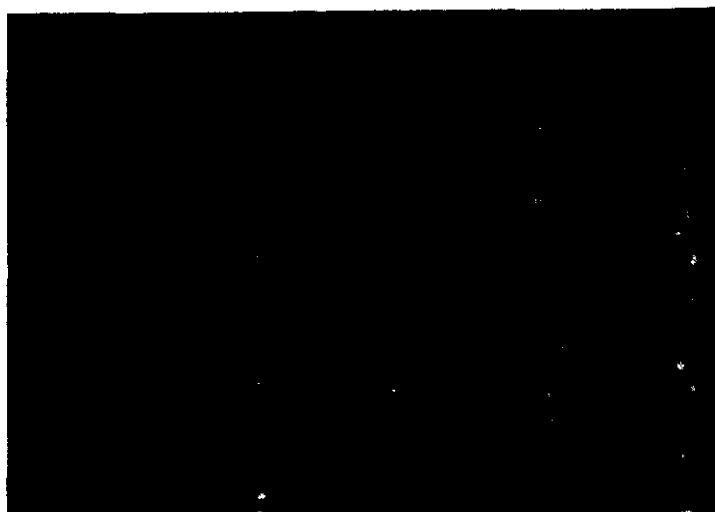
After Blowing Soot-- 65% Recovery

PANEL 1

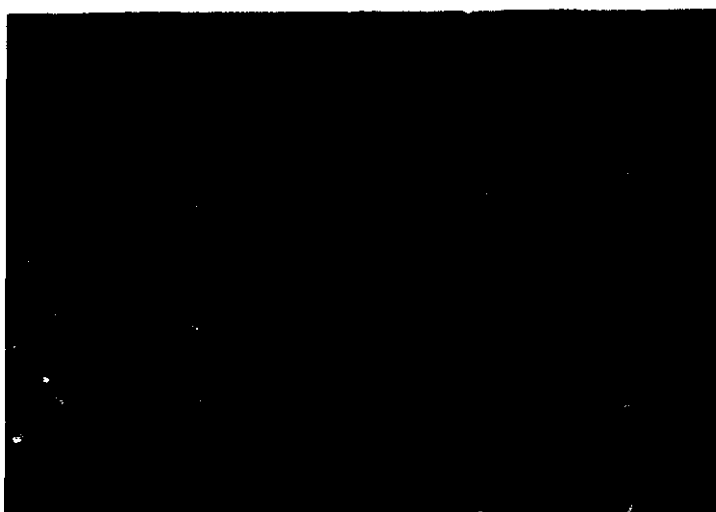
ISLAND CREEK-TEST 1

3.6MBtu/hr, 20% E.A., 2905°F

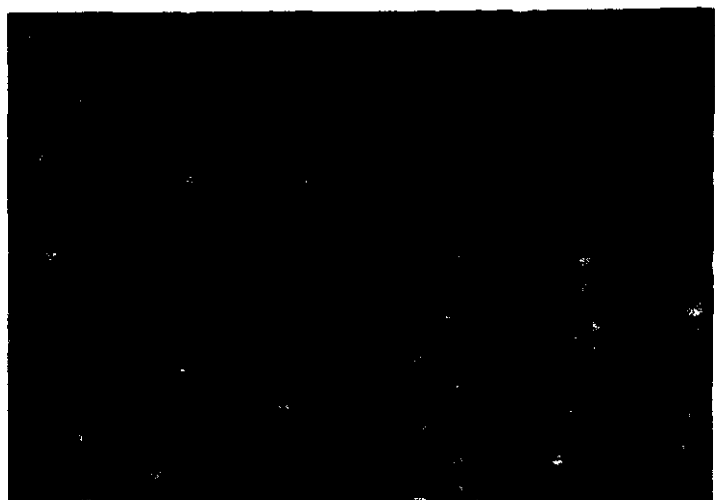
Figure 2.23 Lower Furnace Deposit Buildup-Time Sequencing



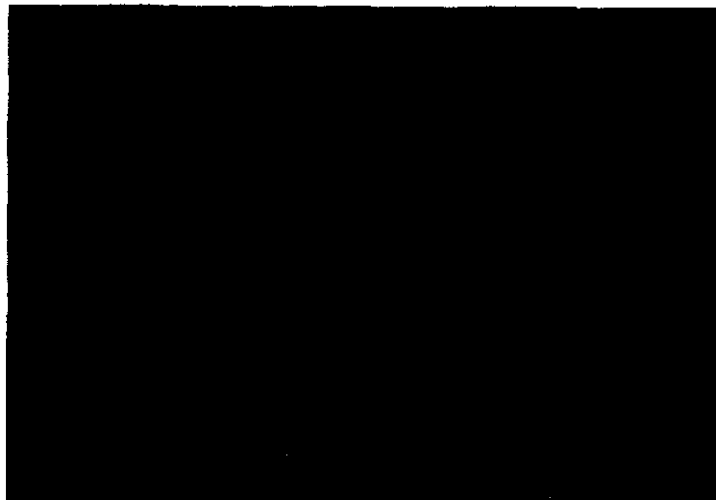
2 HOURS



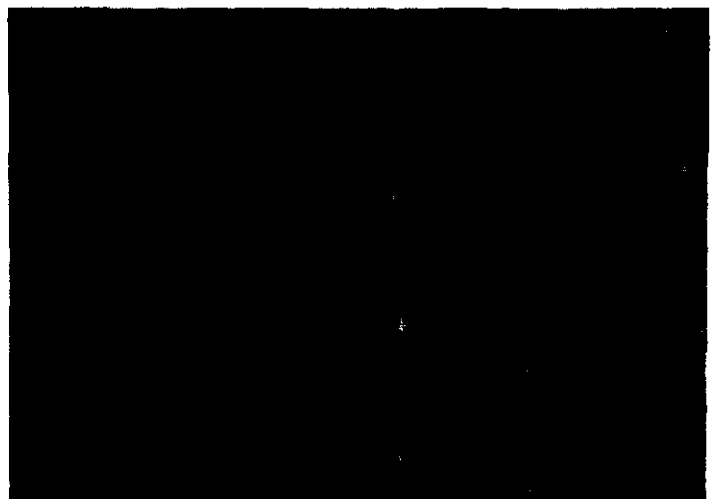
4 HOURS



6 HOURS



8 HOURS



12 HOURS



After Blowing Soot-- 15% Recovery

PANEL 1
ISLAND CREEK-TEST 2
3.8MBtu/hr, 20% E.A., 2946°F

Figure 2.24 Lower Furnace Deposit Buildup-Time Sequencing



2 HOURS



4 HOURS



6 HOURS



8 HOURS



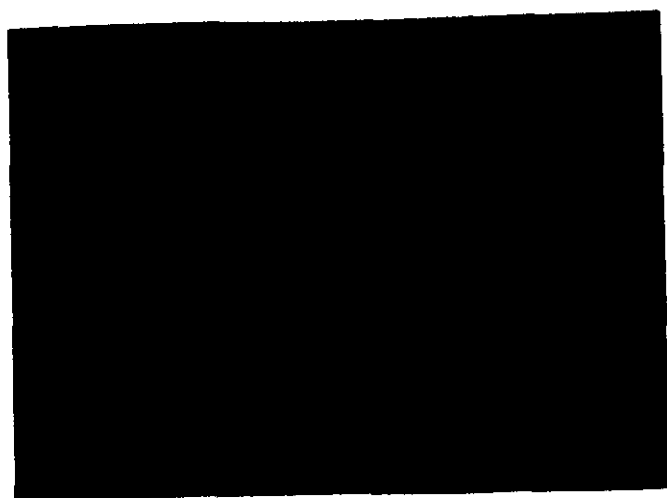
12 HOURS



After Blowing Soot-- 72% Recovery

PANEL 1
ISLAND CREEK-TEST 3
3.5MBtu/hr, 20% E.A., 2870°F

Figure 2.25 Lower Furnace Deposit Buildup-Time Sequencing



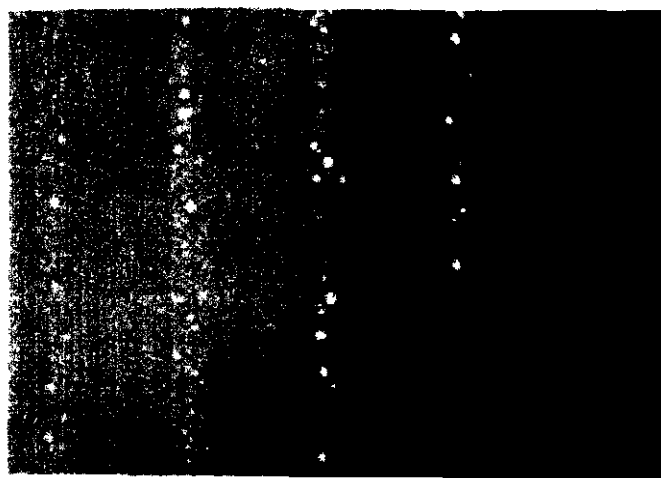
2 HOURS



4 HOURS



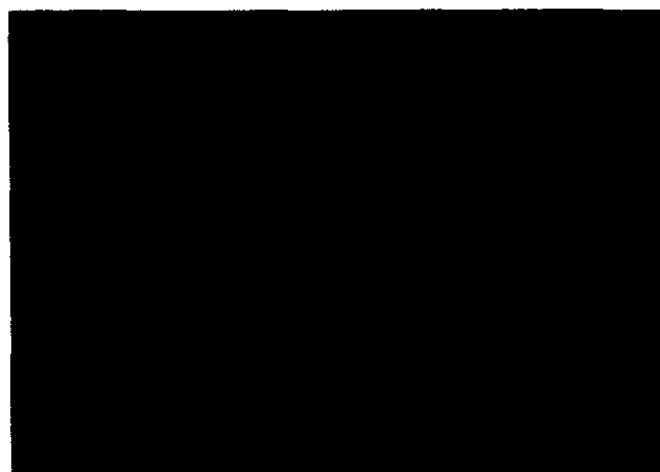
6 HOURS



8 HOURS



12 HOURS



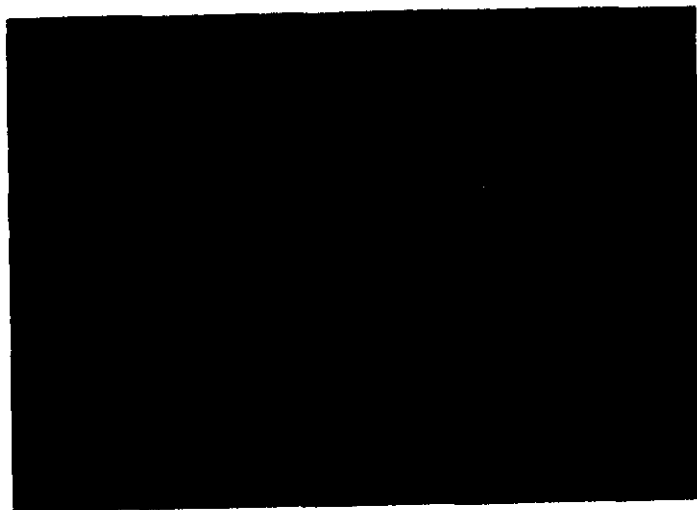
After Blowing Soot-- 40% Recovery

PANEL 1
ISLAND CREEK-TEST 5
3.6MBtu/hr, 10% E.A., 2917°F

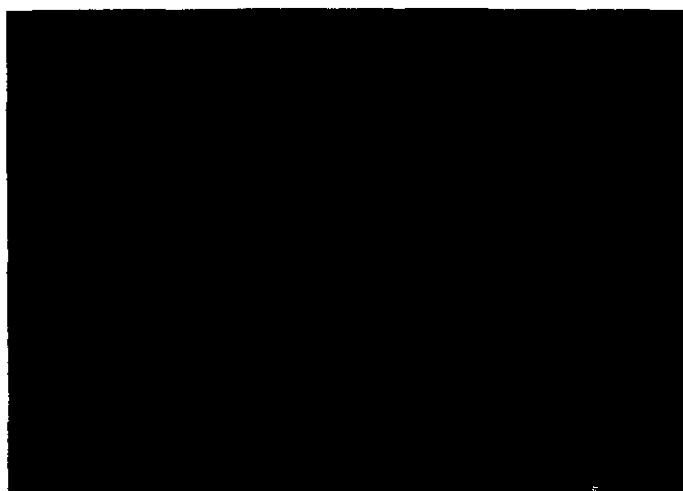
Figure 2.26 Lower Furnace Deposit Buildup-Time Sequencing



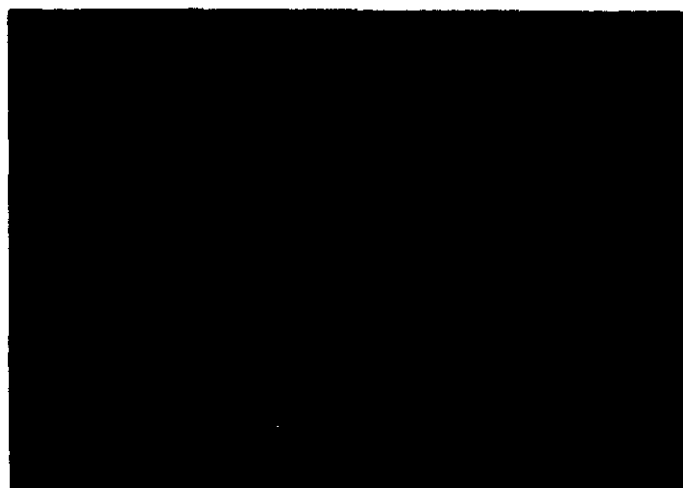
2 HOURS



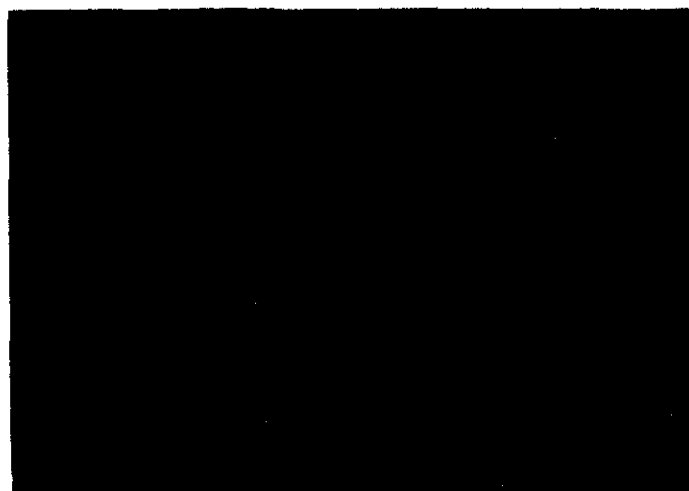
4 HOURS



10 HOURS



12 HOURS



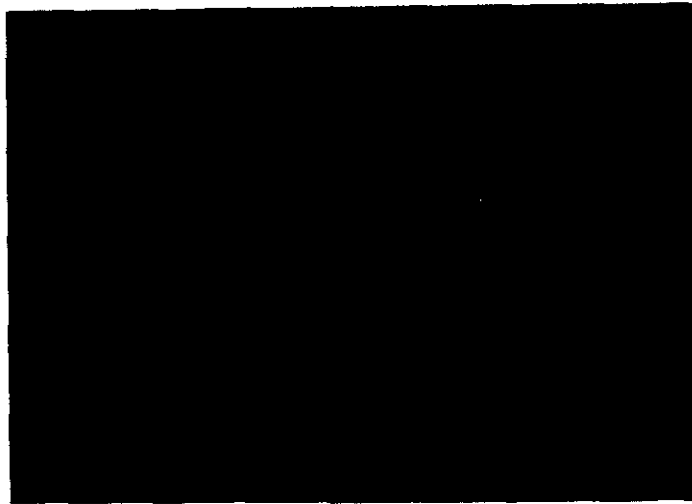
After Blowing Soot-- 17% Recovery

PANEL 1
ISLAND CREEK-TEST 6
3.4MBtu/hr, 10% E.A., 2888°F

Figure 2.27 Lower Furnace Deposit Buildup-Time Sequencing



2 HOURS



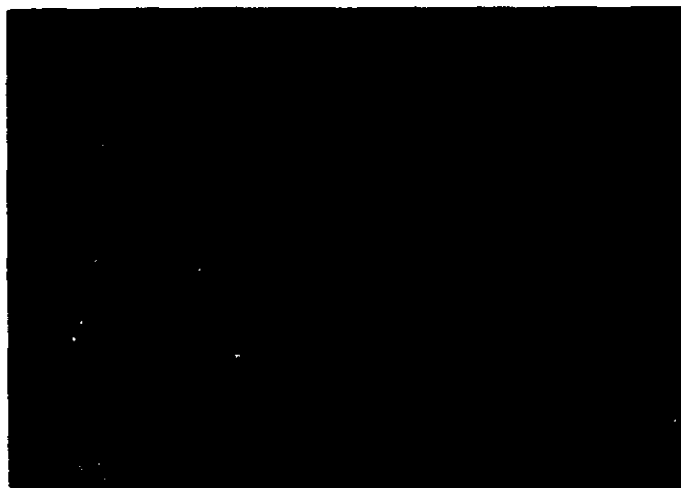
4 HOURS



6 HOURS



8 HOURS



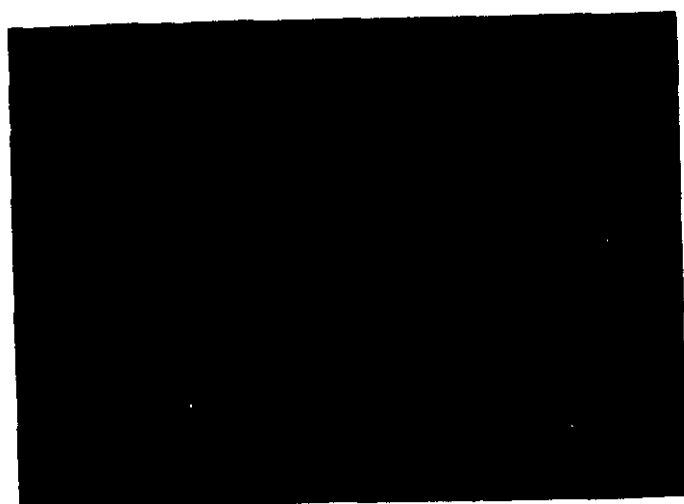
12 HOURS



After Blowing Soot-- 79% Recovery

PANEL 1
ISLAND CREEK-TEST 7
3.2MBtu/hr, 10% E.A., 2833°F

Figure 2.28 Lower Furnace Deposit Buildup-Time Sequencing



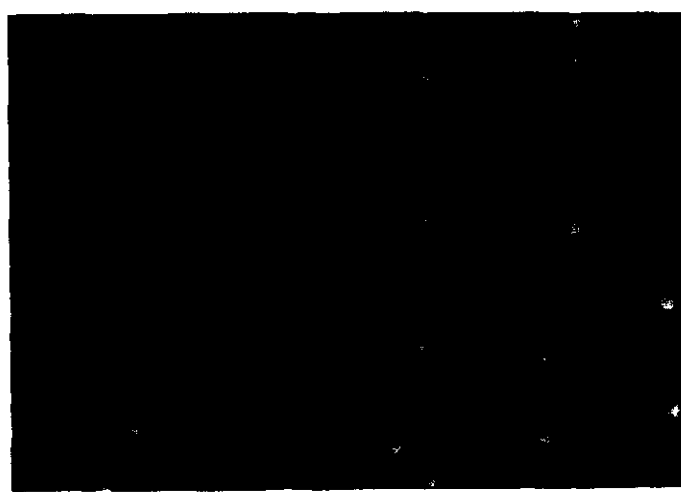
2 HOURS



4 HOURS



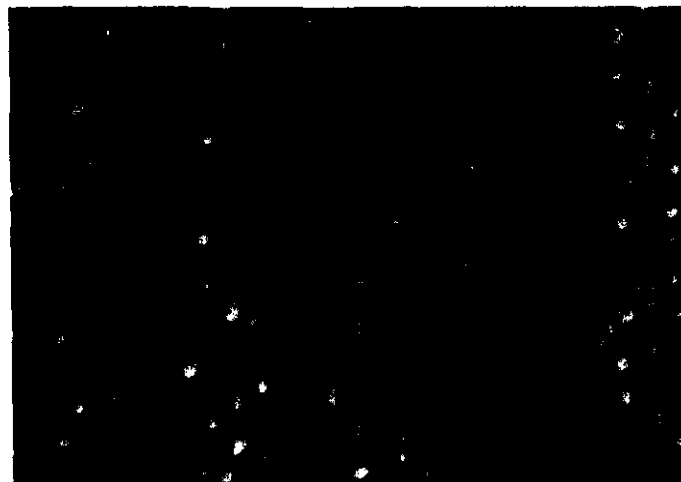
6 HOURS



8 HOURS



12 HOURS



After Blowing Soot-- 69% Recovery

PANEL 1
ISLAND CREEK-TEST 8
3.6MBtu/hr, 30% E.A., 2908°F

Figure 2.29 Lower Furnace Deposit Buildup-Time Sequencing

thermal load and temperature were increased the deposits became more molten and built-up more quickly for both coals. The above mentioned thermal loads and temperatures are considered the critical conditions for each of these coals at the respective excess air levels. The critical conditions are summarized in Table 2.5. All the critical conditions were determined by testing at different thermal conditions in an attempt to "bracket" the conditions where waterwall deposits on Panel P1 were found to be marginally cleanable. The critical condition for the Jader coal at 20% excess air was determined to be 4.0 MBtu/hr and 3010°F (this condition represents the maximum heat input for the FPTF); the cleanability at these conditions was 65%. Though it was not possible to bracket the critical conditions for this case, if a higher thermal load and temperature condition were possible to test, it is likely that the deposit cleanability would have been below 60% and the deposit considered uncleanable.

**Table 2.5 Critical Conditions for Marginal Waterwall
Panel 1 Deposits in the FPTF**

<u>Coal</u>	<u>Excess Air</u>	<u>Firing Rate</u>	<u>Temperature</u>
Jader	20%	4.0MBtu/hr	3010°F
Jader	10%	3.6 MBtu/hr	2910°F
Island Creek	20%	3.6 MBtu/hr	2910°F
Island Creek	10%	3.2 MBtu/hr	2830°F

Lower furnace waterwall deposits ranged from highly sintered to molten during testing of both the Island Creek and Jader coals. The deposits became more molten with time and with increasing flame temperatures for both cases. The physical state of the deposit has a significant effect on heat transfer. In general, molten deposits have a

higher emissivity than sintered or powdered deposits; however, molten deposits are generally thinner than sintered deposits. The decrease in heat transfer is a result of a combination of radiative properties (emissivity) and thermal resistance (thermal conductivity) of a deposit. The effect on heat transfer of a waterwall deposit is a function of coal composition, firing conditions and boiler design. Waterwall deposits that were collected during testing were submitted to the University of North Dakota for analyses; the results of these analyses are shown in Appendix A.

Lower furnace deposit thermal conductances were measured on-line in the FPTF at the end of each twelve-hour test period. This measurement is obtained through Fourier's Law of thermal conduction:

$$\frac{Q}{A} = \frac{k}{\Delta x} (T_s - T_p) \quad 3.1$$

Where Q/A is the panel heat flux (Btu/hr/ft²), $k/\Delta x$ is the overall deposit conductance (Btu/hr/ft²/°F), T_s is the fireside deposit surface temperature, and T_p is the panel surface temperature. The deposit surface temperature is measured by placing a platinum/rhodium thermocouple on the deposit surface in several places, as shown in Figure 2.30, to get an average surface temperature. The panel surface temperature is measured with thermocouples embedded in the surface of the panel, and the heat flux is calculated, as described previously, by means of an energy balance on the temperature rise and flow rate of the heat exchanger fluid. Table 2.6 shows the average thermal conductance ($k/\Delta x$) of FPTF-generated deposits at various elevations, as well as an overall average $k/\Delta x$ of the three elevations. The thermal conductances were in most cases somewhat higher for the Jader coal ash deposits when compared to the Island Creek deposits thermal conductances. However, the differences are more pronounced in the 20% excess air cases compared to the 10% excess air cases; for these two coals it appears that the lower excess air tended to bring about convergence of the thermal conductances of the deposits. Higher FOTs would be generated if heat transfer in the lower furnace was restricted as indicated by the lower

thermal conductance of the Island Creek coal deposits. The results for the 20% excess air cases agree well with the elevated FOTs observed during the field testing of the Island Creek coal when compared to the Jader coal. The average FOT during testing of the Jader coal was approximately 2250°F, the average FOT during the Island Creek testing was approximately 2320°F. Another minor contributor to the increased FOT during the Island Creek could be due to the differences in reactivity of the two coals. Bench-scale tests showed the Jader coal to be more reactive than the Island Creek coal and this could result in slightly delayed ignition which in turn could “push” the flame off the burners and result in slightly higher FOTs. It should be noted that the Jader coal was fired at 255 MW while the Island Creek coal was fired at 250 MW.

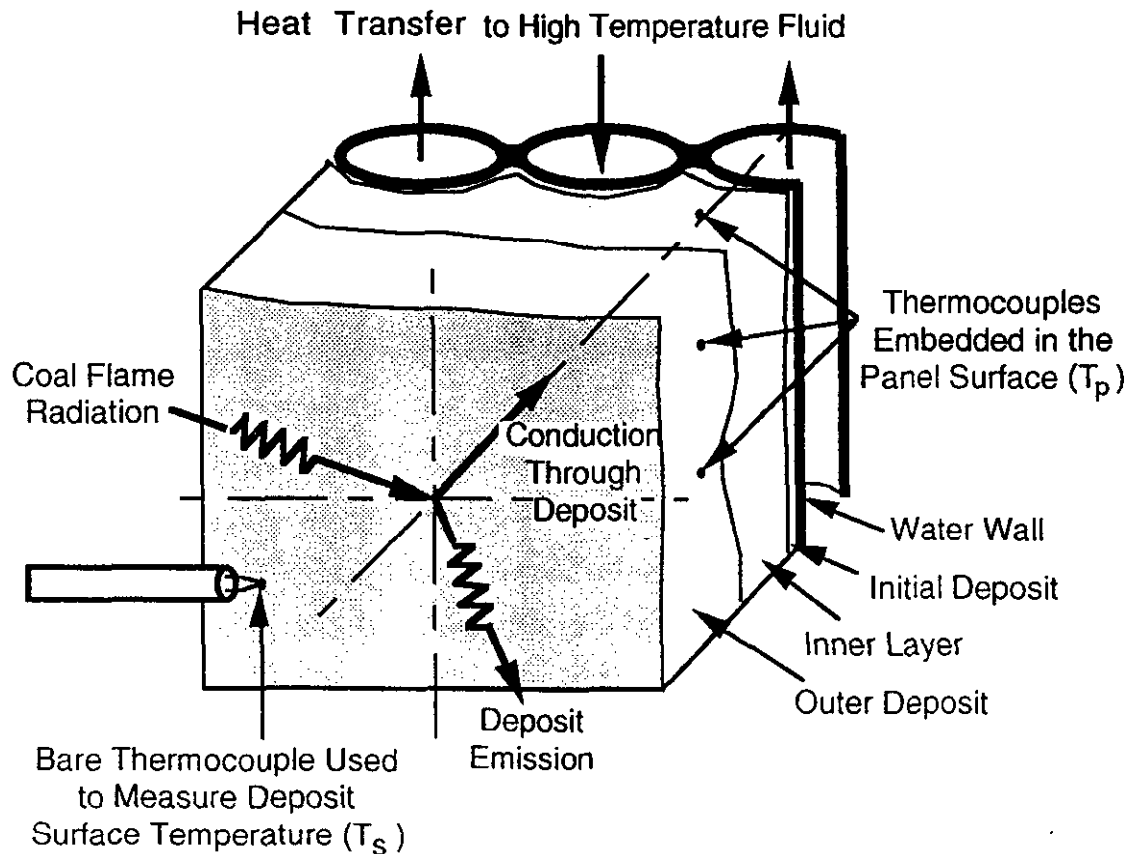


Figure 2.30 Panel Deposit Heat Balance and Thermal Conductance Measurement Technique

Fuel	Island Crk 20%EA	Jader 20%EA	Island Crk 10%EA	Jader 10%EA
Panel 1	41	46	50	48
Panel 3	40	47	43	48
Panel 4	38	44	44	45
Average $k/\Delta x$	40	46	46	47

Table 2.6 Thermal Conductances of Deposits Generated at Various Elevations in the FPTF (Btu/hr-ft² °F)

Convective Pass Fouling

Fouling characteristics are evaluated in the FPTF by two methods, bonding strength measurements (BSM) and deposit build-up rates. Bonding strength measurements are determined by allowing deposits to build-up on simulated superheater tube surfaces undisturbed. The deposit growth is observed and documented in photographs at periodic intervals. When deposits reach a thickness (out from tube surface) of 3 to 4" a BSM is taken on the deposit. To obtain the BSM a penetrometer is used to "push" the deposit off the tube surface. The penetrometer provides a measurement of the force required to remove the deposit. Suction pyrometer measurements provide temperature data for comparison of BSMs at different temperatures. Deposit build-up rates are determined in conjunction with the BSMs. The amount of deposition is documented in observations and photographs and when the deposits have reached a thickness of 3 to 4" the build-up time is recorded along with all deposit characteristics. The BSMs and the build-up rates can then be used to compare different fuels fired in the FPTF at similar conditions.

Fouling characteristics, specifically bonding strengths found during pilot-scale testing, along with some points taken during field testing at the Watson Unit are summarized in Figure 2.31. In general, the bonding strength increased with increasing local gas temperatures and the bonding strengths of superheater deposits formed during the

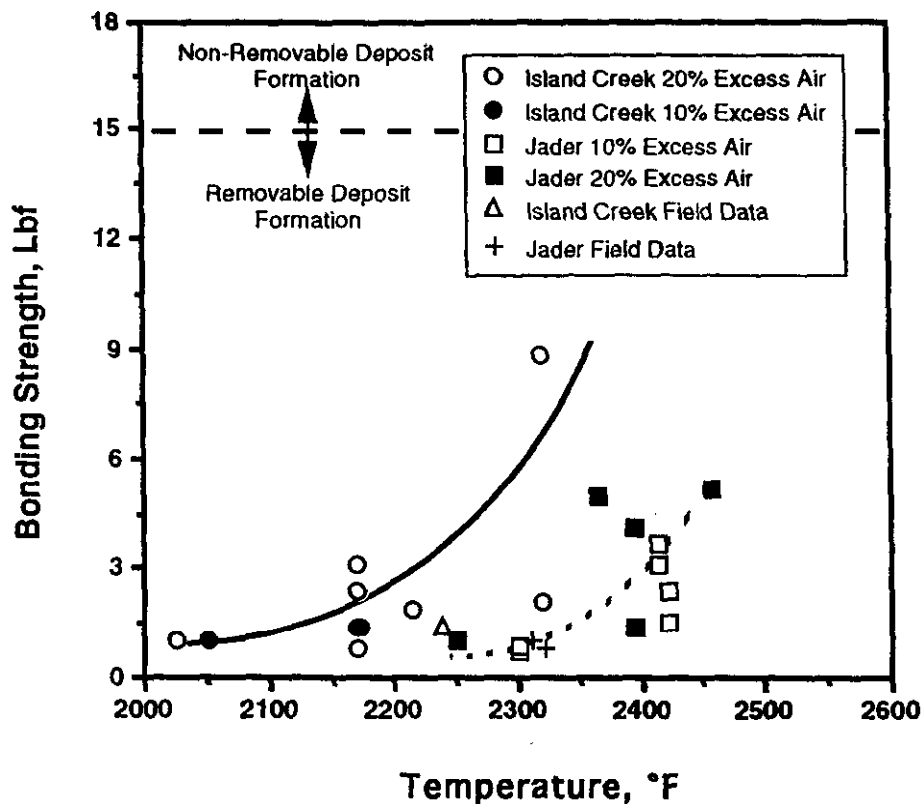


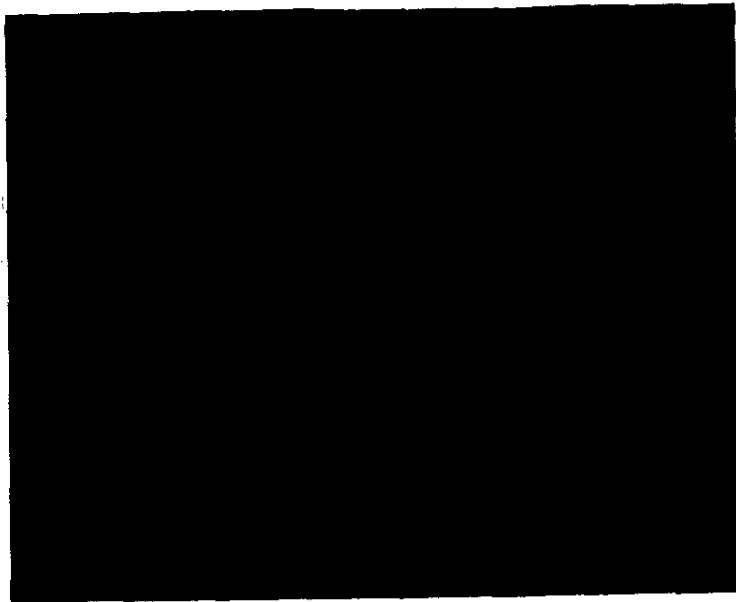
Figure 2.31 Bonding Strength Comparison of Watson Coals

Jader testing were lower (more readily removable) at similar temperatures when compared to the Island Creek coal. Bonding strength measurements taken in the field were all low and similar at similar temperatures when compared to the FPTF data. There were no significant differences in superheater deposit bonding strength for either coal as a function of varying excess air. Deposits which formed on simulated superheater tube surfaces in the convective section of the furnace were generally sintered at all gas temperatures tested (2000 to 2450°F). Deposit bonding strength increased with increasing gas temperature for each coal fired, but never resulted in deposits which exceeded the cleanability level. Based on previous data from field tests and pilot-scale evaluations, it is generally considered that bonding strengths of 15 or lower are indicative of deposits which are cleanable with conventional soot

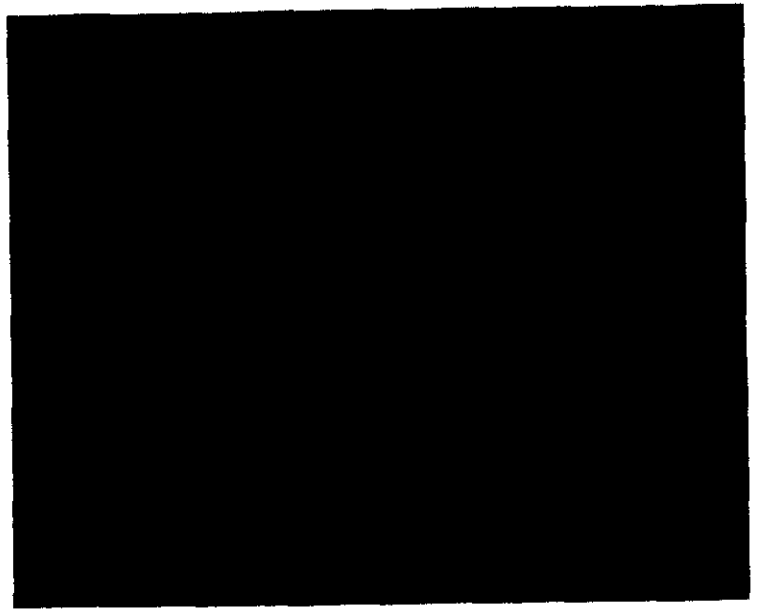
blowers. Usually removal of the deposit leaves a 1/16" to 1/8" layer of hard bonded scale which is very difficult to remove, since this layer would not be removed during conventional sootblowing in the field it is left as is. This coated condition more accurately simulates seasoned superheater tubing than does bare metal. After bonding strength measurements are taken all the deposits are then blown down the FPTF backpass and a new cycle is started. The highest bonding strength values observed during these series of tests were ~9 at ~2400°F for the Island Creek coal and ~6 at ~2450°F for the Jader coal.

Time-sequenced photographs of superheater tube depositions for the two coals tested at two different gas temperatures appear in Figures 2.32 to 2.35. The first (IA) superheater probe bank is depicted (deposition on the second superheater probe bank (IIC) was minimal and deposits which did form, sloughed off by themselves), and the firing rate and local gas temperature are provided for each series. These photographs document qualitative deposit buildup rates and deposit physical characteristics. It is also apparent from this series of photographs that once tube deposition initiates at specific sites, these deposited sticky particles retain additional impacting particles. Deposit growth thus proceeds in both a lateral direction (covering additional tube surface) and an outward direction (increasing deposit thickness on a given tube surface).

As shown in Figures 2.32 to 2.35, the deposition rates increased greatly with increased temperature. It should be noted that higher temperatures are usually the effect of increased thermal load, i.e. more coal input therefore more ash input. The Jader coal could be fired at higher thermal loads and temperature from a lower furnace slagging standpoint, consequently, the Jader tests provide fouling data at higher gas temperatures. The data available at similar temperatures shows that the Jader coal superheater deposits were bonded less tenaciously than those of the Island Creek coal. It should be noted that all the bonding strength measurements taken during the testing of the Jader and Island Creek coals were below the value which would be



1 Hours



2 Hours



4 Hours



6 Hours

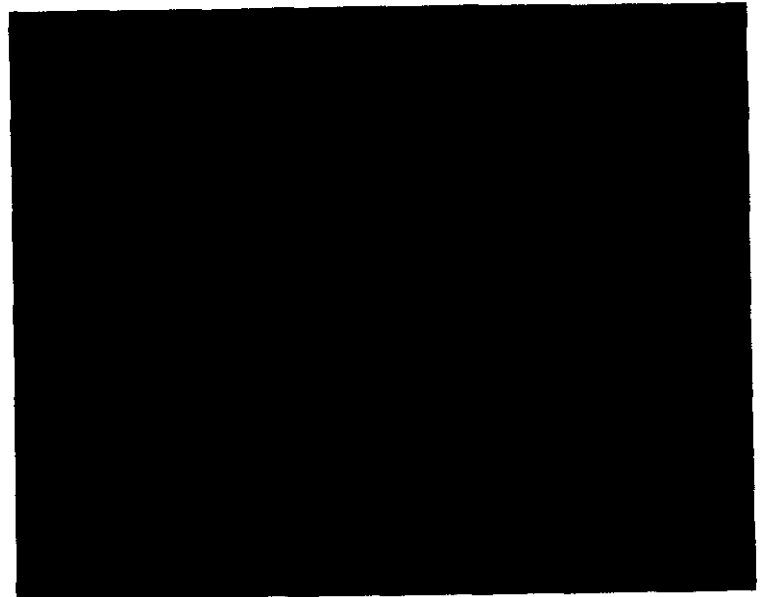
Bonding Strength Measurement 5.2

SUPERHEATER DUCT 1
JADER - TEST 3
Gas Temperature 2411°F

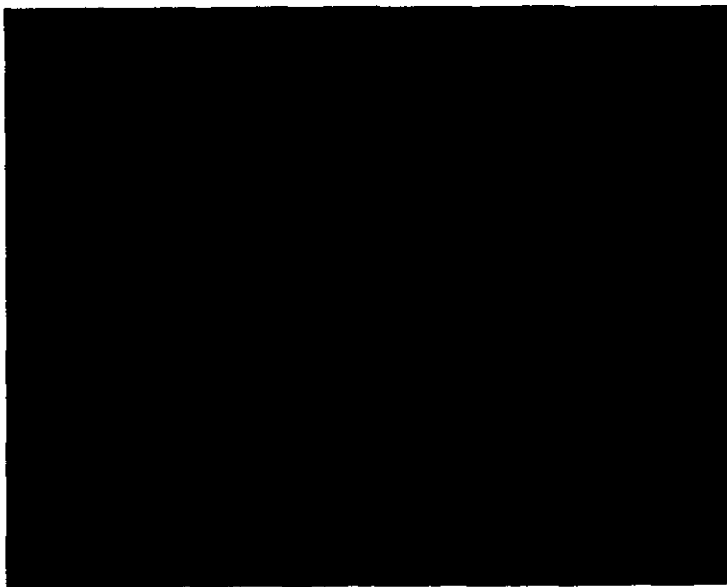
Figure 2.32 Upper Furnace Deposit Buildup - Time Sequencing



1 Hours



4 Hours



8 Hours

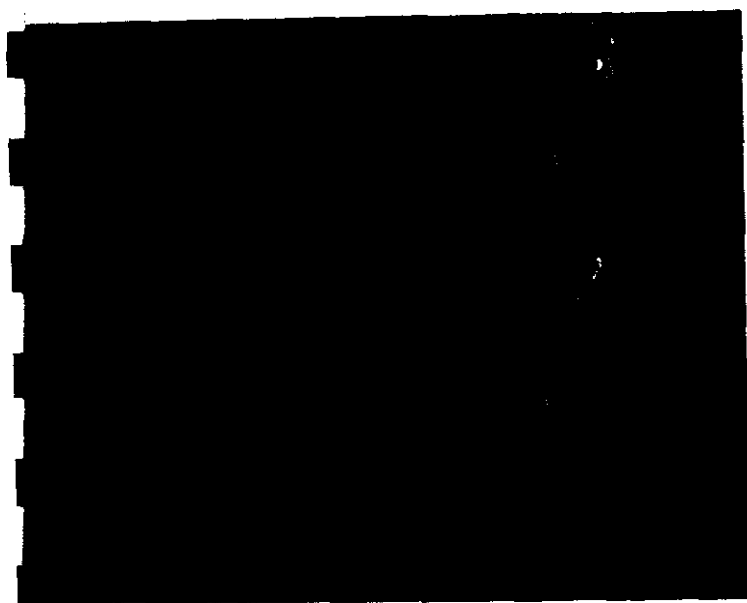


12 Hours

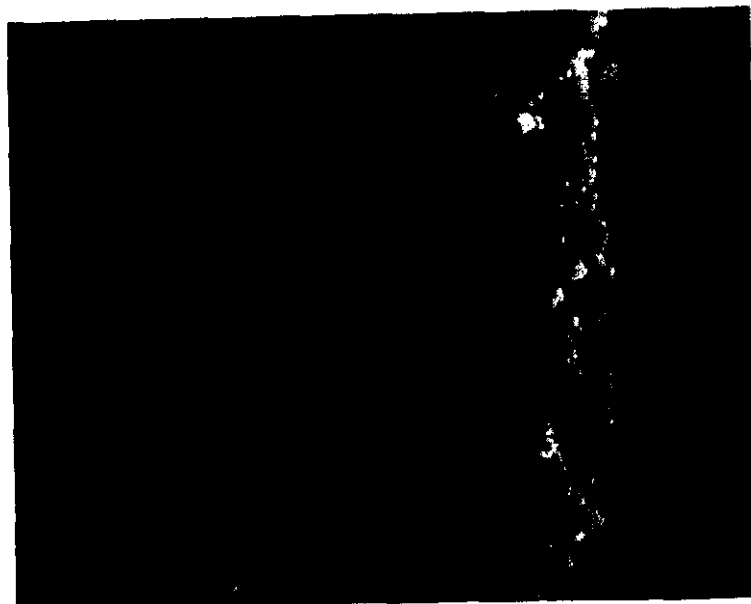
Bonding Strength Measurement 0.0

SUPERHEATER DUCT 1
JADER - TEST 8
Gas Temperature 2258°F

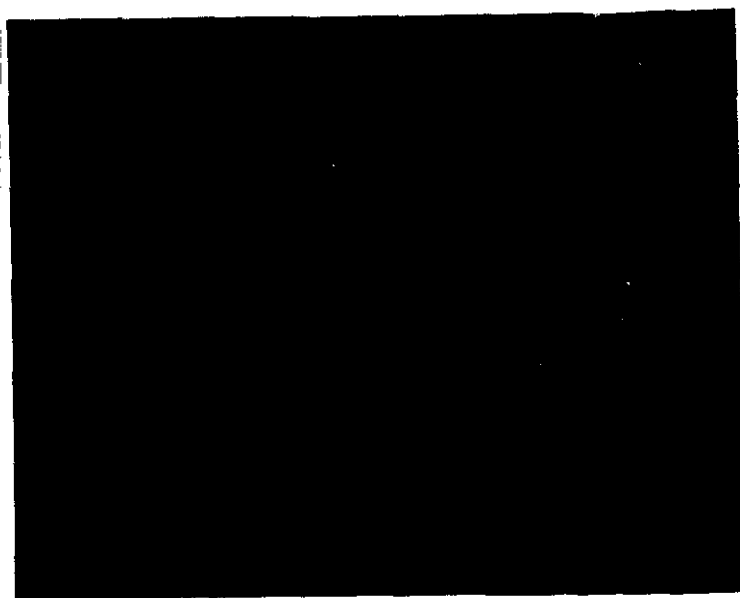
Figure 2.33 Upper Furnace Deposit Buildup - Time Sequencing



2 Hours



4 Hours



6 Hours

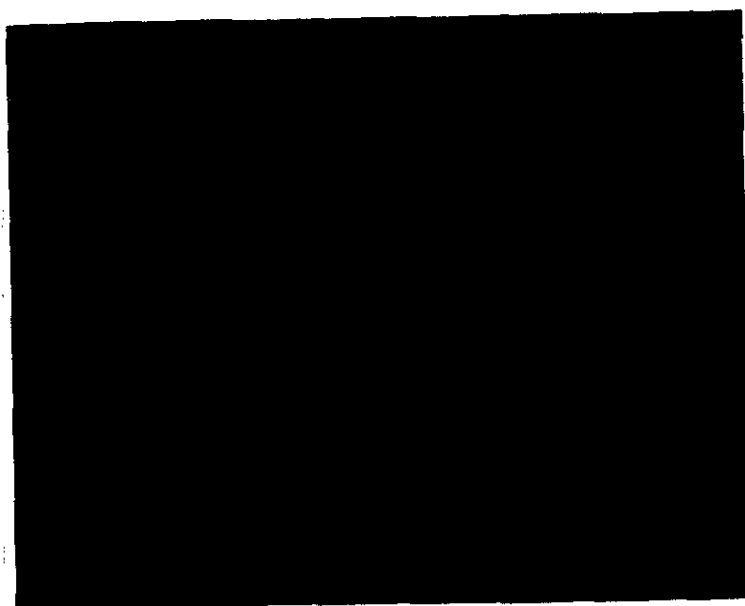


10 Hours

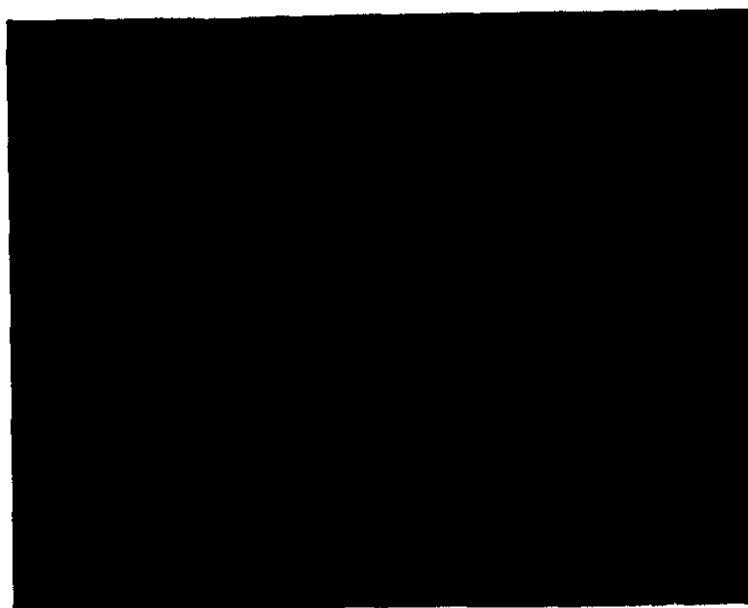
Bonding Strength Measurement 8.8

**SUPERHEATER DUCT 1
ISLAND CREEK - TEST 2
Gas Temperature 2324°F**

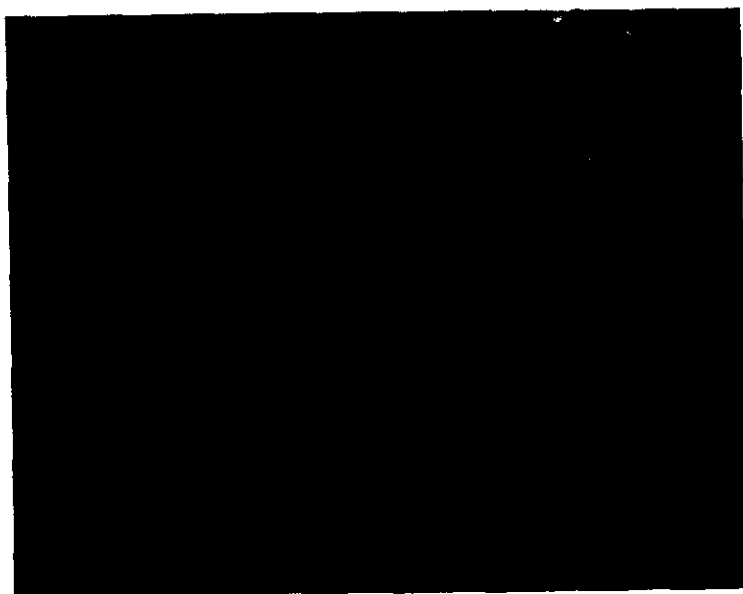
Figure 2.34 Upper Furnace Deposit Buildup - Time Sequencing



2 Hours



4 Hours



6 Hours



10 Hours

Bonding Strength Measurement 0.0

SUPERHEATER DUCT 1
ISLAND CREEK - TEST 5
Gas Temperature 2235°F

Figure 2.35 Upper Furnace Deposit Buildup - Time Sequencing

considered unremovable by conventional sootblowing methods. Both coals have low relative fouling potentials and should not create high temperature fouling problems in sections at gas temps below 2450°F.

Superheater deposit build-up rates were similar for the coals at similar temperatures and firing rates. At the 3.6 MBtu/hr firing rate and an average superheater Duct I temperature of around 2250°F sootblowing of the superheater probes was required every 10 to 12 hours for both coals. At 4.0 MBtu/hr and average superheater Duct I temperature of 2411°F sootblowing was required every 6 hours when firing Jader coal. At 3.8 MBtu/hr and average superheater Duct I temperature of 2324°F sootblowing was required every 8 to 10 hours when firing Island Creek coal. It should be emphasized that at all conditions encountered during these tests the superheater deposit bonding strengths were low and fouling should be controllable through conventional sootblowing procedures.

Fly Ash Erosion

Fly ash erosion is evaluated in a special high velocity test section located in the back pass of the FPTF. A temperature controlled convection tube containing an irradiated metal test ring is placed in the flue gas stream where the flue gas velocity has been increased to approximately 180 to 240 ft/sec. The erosion is determined by measuring the metal loss of the test ring over a measured period of time, with a known ash quantity and at a measured velocity. The results are then normalized to a velocity of 60 ft/sec. The metal loss is determined using a special surface activation technique based on measuring radiation intensity of the test ring before and after exposure to the flue gas stream.

The results from the erosion measurements are presented in Table 2.7. The results show that the Jader coal was slightly more erosive than the Island Creek coal during FPTF testing. However, erosion results were fairly similar and the higher erosion rate

appears to be attributed to the higher ash content of the Jader coal. The relative erosion rates for both coals would be considered low. Figure 2.36 presents some normalized erosion rates for other coals tested in the FPTF along with the Jader and Island Creek coals. Figure 2.36 shows that the Jader and Island Creek erosion rates were low when compared to many of the other coals fired in the FPTF.

Table 2.7 Erosion Results For Watson Coals

	<u>Island Creek</u>	<u>Jader</u>
Un-normalized Wear, (μ)	4.8	6.2
Gas Velocity, (ft/sec)	236	243
Ash Loading, (lb/hr)	12.6	14.0
Normalized Wear, (mils/ 10,000 hrs @ 60 ft/sec)	0.5	0.6
Critical Velocity, (ft/sec for 2 mils wear in 10,000 hrs)	90.9	85.4

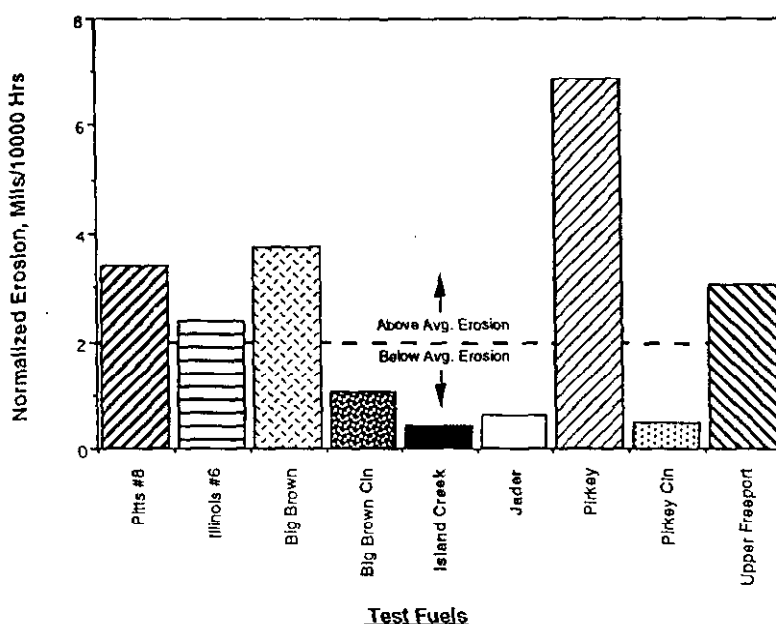


Figure 2.36 Watson Erosion Comparison

Section 3

BOILER PERFORMANCE MODELING

The purpose of the ABB boiler performance modeling was threefold. Firstly, the model calculated data points not obtained during field testing due to economic or physical limitations. For example, the furnace gas temperature profile from burner elevation through the economizer surface is important for interpretation of boiler performance and deposit behavior. However, due to economic restraints, large boiler dimensions and the availability of access ports, it is generally not possible to “map” gas temperature for the entire boiler. The boiler performance model, through the use of mass and energy balances, uses data available (steam temperatures, steam flowrates, etc.) from the plant data logging systems to back-calculate an average gas temperature at the furnace outlet plane, and at the inlet of each convective section. Additionally, model outputs can be used to assess field data quality and resolve inconsistencies between measurements.

The second purpose of the boiler performance model was to provide information on performance parameters not measured during field testing. Certain values, such as lower furnace thermal conductance and peak flame temperature, are not directly measured in the field because of the technical difficulty in obtaining reliable data. These parameters are essential for correlation to laboratory data and algorithm development.

Lastly, the boiler model supports the CQE model development through the resolution of the boiler performance data. ABB model results provide a basis for comparison of CQE boiler model predictions. This may help to identify specific areas of the CQE model requiring additional development and aid in validating other aspects.

Data from the Watson Unit 4 data logging system, the pilot-scale test furnace (FPTF) and special bench-scale tests were used as quantitative and qualitative inputs to an in-house computer model of the boiler and auxiliary equipment. Included in the boiler island was the pulverizers, air heaters and the steam generator. Once the information was processed through the model, the impacts of firing the Jader (baseline) and Island Creek (alternate) fuels in Watson Unit 4 were evaluated. Comparisons were then made between the commercial boiler performance firing Jader and Island Creek coals. Specific performance areas that were evaluated include:

- Overall boiler efficiency
- Boiler capacity (load limitations due to slagging, fouling, erosion or other factors)
- Lower furnace performance (heat release, heat absorption distributions, outlet temperature)
- Convection pass performance (heat absorption rates, exit gas temperature)
- Air heater performance (air temperature rise, gas side efficiency)
- Pulverization (power consumption and capacity)

The consequences and anticipated advantages/disadvantages of firing the Jader and the Island Creek fuel in the Watson Unit 4 are discussed herein.

3.1 DESCRIPTION OF WATSON UNIT 4

The Jack Watson Unit 4 Steam Plant of Mississippi Power is a Riley Stoker designed, opposed fired, balanced draft, natural circulation drum unit, with a split back-pass arrangement. The unit was designed to burn a high sulfur (3.7%) Alabama coal with a HHV of 12,000 Btu/lb and a grindability of 55 Hardgrove. Boiler capacity is 1,779,000 lb/hr of main steam flow and 1,565,500 lb/hr of reheat steam flow; main and reheat outlet conditions are 1000°F/2400 psig and 1000°F/561 psig respectively.

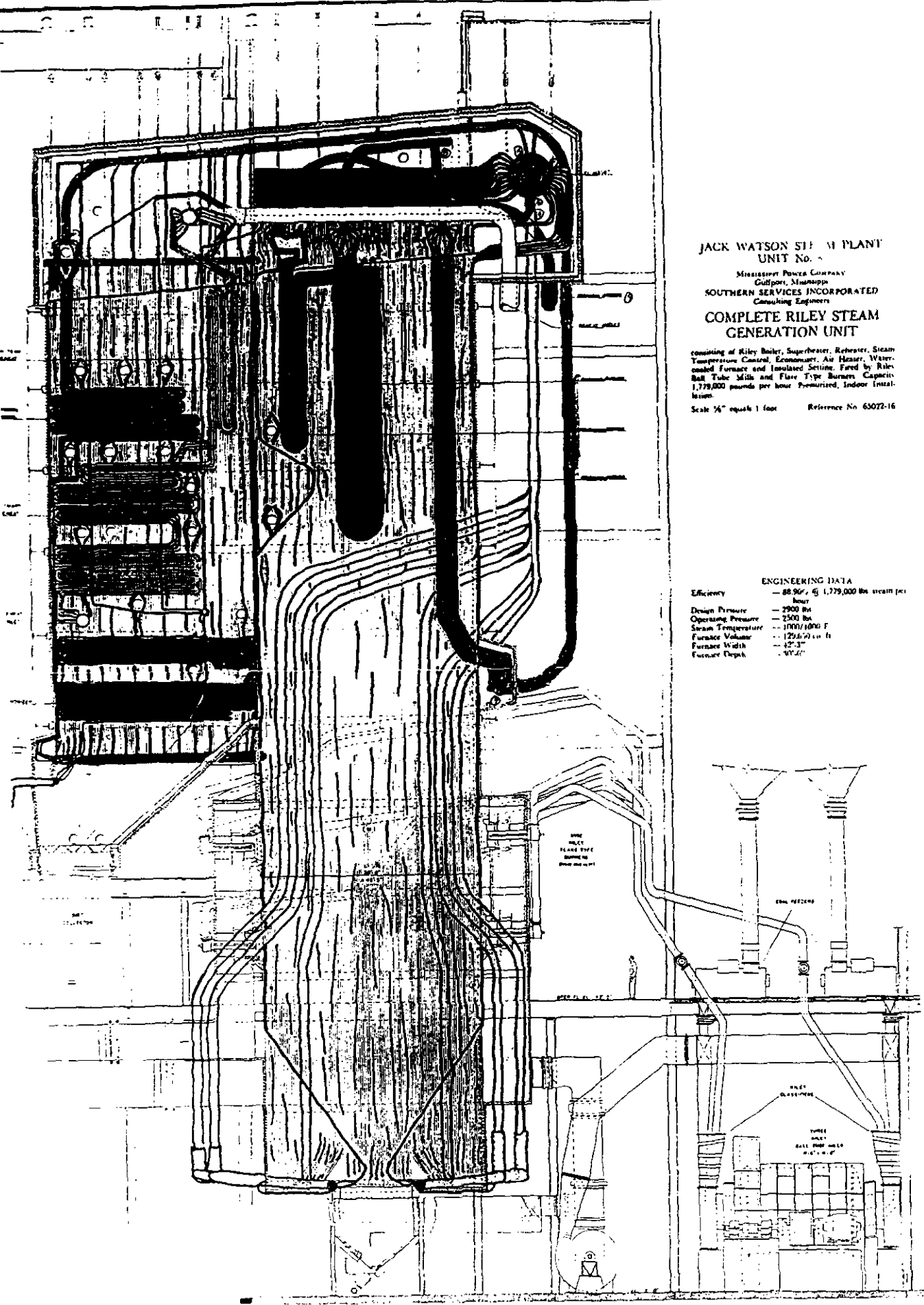
The furnace is 42.25 feet wide by 30 feet deep. The superheater train consists of, in order, (1) radiant roof, (2) horizontal low temperature section, (3) upper furnace wing walls, (4) attemperators, (5) pendant platen assemblies and (6) pendant finishing section. The reheater arrangement utilizes a pendant convective section after the finishing superheat and a horizontal low temperature section under the superheat low temperature section. The back-pass split begins immediately following the finishing reheater. The convective pass is split approximately 3:1 based on cross-sectional area with the low temperature reheater and superheater on one side and an economizer section in both sides, as shown in Figure 3.1.

Coal is pulverized in three Riley Double Ended Ball Tube Mills. Each mill has a capacity of 70,600 lb/hr at 70% through 200 mesh when moisture does not exceed 12%, and the Hardgrove grindability is 45 or higher. The pulverized coal is admitted to the furnace through two elevations of opposed wall firing. A total of 18 burners are present with ten at the top elevation and eight at the lower. Combustion air is preheated through two Air Preheater Parker 27 H 67.5 bisector air heaters.

3.2 BOILER OPERATION

Watson Unit 4 furnace operation is plagued with slagging problems associated with the current coal at a maximum load of 265 MW (gross). However, continuous operation without slagging problems is achievable at a lower load of 250 MW (gross). Observations by plant personnel indicate that slagging problems are more commonly experienced on the North (left) side of the boiler. Another problem associated with maximum load (265MW) operation was high superheater temperatures. An imbalance in north/south gas temperatures and operating O₂ level has also been noted.

Normal operating conditions for Unit 4 is MCR, firing 250-255 MW. The furnace sidewalls have been replaced with spiral walled tubes which have significantly



JACK WATSON STEAM PLANT
UNIT No. 4
 MISSISSIPPI POWER COMPANY
 Gulfport, Mississippi
SOUTHERN SERVICES INCORPORATED
 Consulting Engineers
COMPLETE RILEY STEAM
GENERATION UNIT

consisting of Riley Boiler, Superheater, Reheater, Steam
 Temperature Control, Economizer, Air Heater, Water-
 cooled Furnace and Insulated Settings. Fired by Riley
 Ball Tube Mills and Flare Type Burners. Capacity
 1,779,000 pounds per hour. Premixed, indoor install-
 ation.
 Scale 1/4" equals 1 foot Reference No. 65072-16

ENGINEERING DATA

Efficiency	— 88.96% @ 1,779,000 lbs. steam per hour
Design Pressure	— 2900 lbs.
Operating Pressure	— 2500 lbs.
Steam Temperature	— 1000/1000 F
Furnace Volume	— 1294.5 cu. ft.
Furnace Width	— 42'-3"
Furnace Depth	— 97'-0"

Figure 3.1 Schematic Drawing of Watson Unit 4

increased the heat absorption patterns in the lower furnace. The lower furnace is now allowed to slag up, pushing up the heat to the upper furnace and back-pass areas. Sootblowing procedures are currently controlled according to the temperature differences between the superheat and reheat steam temperature. Specific portions of the furnace (commonly selected elevations located above the burner zone) are then blown to alter the heat flux profile and ultimately bring the reheater and superheater steam temperatures close to 1000°F. It is not typical operational procedure to use spray stations to alter steam temperatures.

3.3 COAL SOURCE

Watson Unit 4 is considered a coal test unit for Mississippi Power Company (MPC). MPC currently conducts approximately one test burn each quarter using Watson Unit 4. If the coal can be successfully burned in this unit, it has been demonstrated that the coal will be acceptable in the other coal units in their system. Because of its "test bed" status, Watson Unit 4 has burned many candidate coals over a period of several years, including both acceptable and unacceptable fuels.

The as-received Jader coal's proximate and ultimate analyses are very similar to the original design coal. Standard ASTM fuel analysis results for the as-received Jader and Island Creek coals (sampled before the pulverizers during the Unit 4 testing) are given in Table 3.1. The field coal analyses were used for the field combustion performance modeling to maximize the comparison to field test data. Small differences between the field and pilot-scale analyses are attributed to variations in laboratory techniques and normal fluctuations in fuel supply, since the fuel for pilot-scale testing was a composite blend taken from the feed belt during field testing.

Table 3.1
ANALYSIS OF WATSON UNIT 4 TEST COALS

	<u>Jader</u>	<u>Island Creek</u>
<u>Proximate Analysis, %</u>		
Moisture	6.49	11.66
Ash	8.26	6.10
Volatile	33.97	35.79
Fixed Carbon	51.28	46.45
<u>Ultimate Analysis, %</u>		
Carbon	69.63	65.69
Hydrogen	4.69	4.48
Nitrogen	1.40	1.22
Chlorine	0.29	0.20
Sulfur	2.53	2.53
Oxygen	6.72	8.14
Moisture	6.49	11.66
HHV, Btu/lb	12555	11821
Grindability	62.25	52.50
Total Moisture	4.00	9.04
<u>Ash Reducing Fusion Temp, °F</u>		
Initial	1988	1979
Softening	2055	2030
Hemispherical	2156	2131
Fluid	2298	2300
<u>Ash Oxidizing Fusion Temp, °F</u>		
Initial	2405	2373
Softening	2466	2421
Hemispherical	2503	2465
Fluid	2534	2509
<u>Major Elements in Ash, %</u>		
SiO ₂	42.39	45.77
Al ₂ O ₃	19.09	18.91
Fe ₂ O ₃	21.00	21.09
CaO	3.06	4.67
MgO	1.08	0.76
Na ₂ O	0.36	0.79
K ₂ O	2.06	2.09
TiO ₂	0.78	0.75
MnO ₂	0.05	0.04
P ₂ O ₅	0.19	0.19
SO ₃	2.44	4.10
LiO	0.02	0.03
BaO ₂	0.04	0.20
SrO ₂	<u>0.09</u>	<u>0.04</u>
Total	92.65	99.43

3.4 BOILER PERFORMANCE PROGRAM DESCRIPTION

ABB-CE's Boiler Performance Program (BPP) was used to model the Watson Unit 4 boiler island. The BPP is a computational tool that was developed to select various boiler components for new boiler designs and predict the performance of the system. Calculations are performed for the steam generator envelope and related auxiliary equipment to generate information required for detailed component design. The program is structured in a modular fashion to perform the calculations in a predetermined sequence. Many of the calculated outputs from the nine modules are passed back to preceding modules for iterative solution.

The calculations begin with the Boiler Efficiency Module, which is dependent on the fuel analysis, and the Turbine Heat Balance Module, which in turn is dependent on the steam turbine design. The calculations continue in the same sequence as the flue gas flow through the boiler. Lower furnace performance is calculated first, followed by the convective pass, and then the air heater. The control volumes of the five modules that actually model the boiler envelope are shown in Figure 3.2. The major heat absorption surfaces in the study unit associated with these modules are also identified.

The Efficiency Module calculates overall boiler efficiency using the ASME Power Test Code method (PTC 4.1-1964). Inputs such as carbon heat loss (from the Lower Furnace Program-Slice Kinetic Model, described below), radiation loss (from CE standards), and air heater exit gas temperature (from the Air Heater Module) are updated as the program iteratively converges on a solution.

The purpose of the Heat Balance Module is to determine the heat duty for the boiler from the turbine heat balance data. Air and gas flows are calculated based on the total heat duty required and the boiler efficiency. The module has provisions for main steam, two reheats, and auxiliary steam.

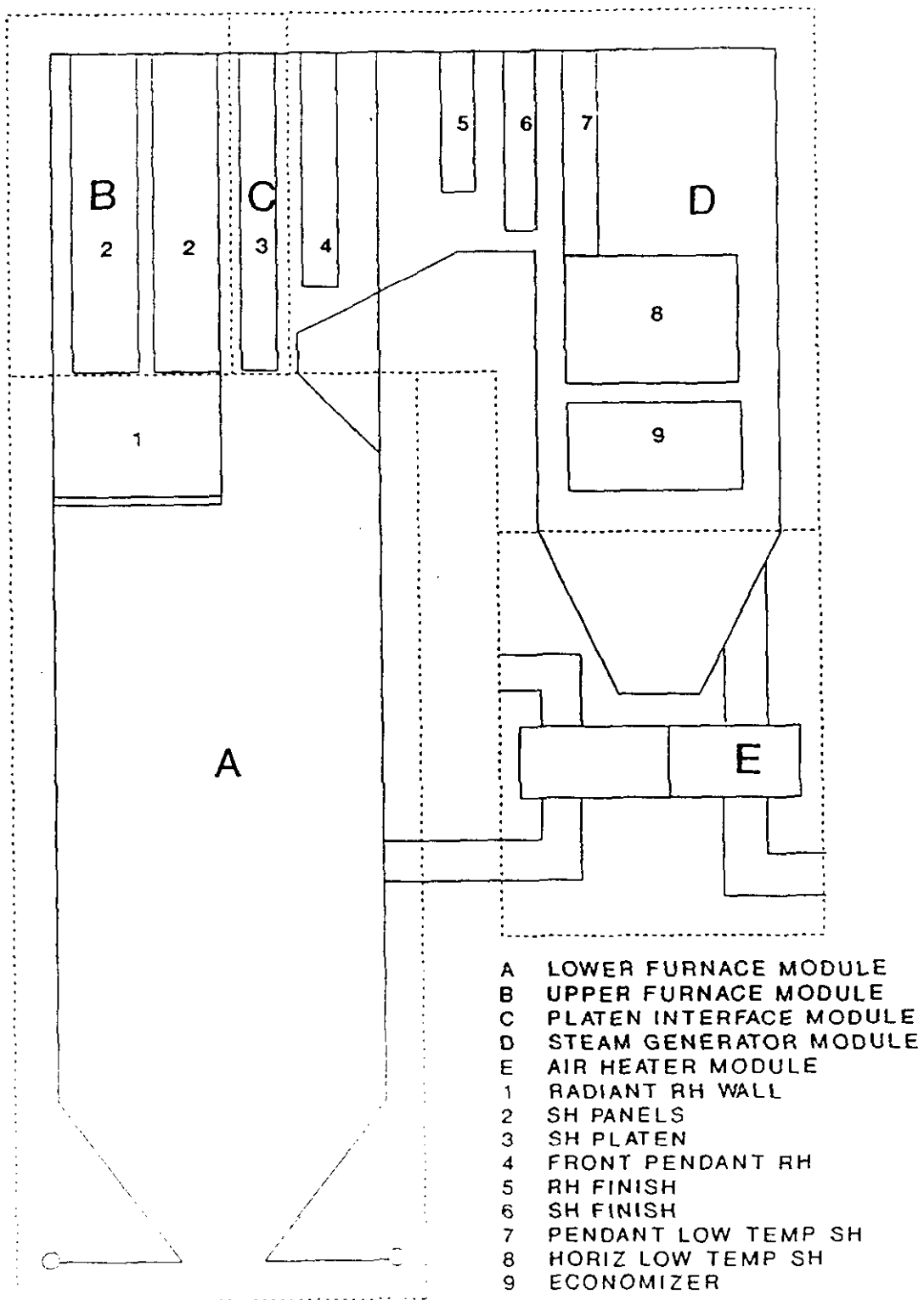


Figure 3.2 Boiler Performance Program Domain

The objective of the Pulverizer Module is to determine primary air temperature requirements so that the heat input to the lower furnace may be calculated in the next module. A heat balance is performed around the mill so that either the amount of moisture evaporated, the air temperature entering the mill, or the mixture temperature leaving the mill is calculated. Mill performance (maximum capacity, mill loading, power input, air quantity and temperature) is also calculated.

The Net Heat Input Module determines the thermal energy available for absorption by the furnace above the selected reference temperature of 80°F. This information is passed to the Lower Furnace Module.

The Lower Furnace Program-Slice Kinetic Model (LFP-SKM) simulates the combustion region of the furnace. The LFP-SKM develops a flame and burn-out profile from fundamental data on the coal combustion kinetics and calculates carbon heat loss (Bueters and Habelt, 1974). The program then determines, through a series of heat balance calculations, the heat transfer from the combustion products to the waterwalls, the corresponding gas temperatures, and furnace outlet temperature.

The purpose of the Upper Furnace Module is to calculate the heat transfer in the upper furnace, the resultant gas temperatures, and radiation to the platens and the convective pass of the boiler. The upper furnace outlet gas properties are utilized in the subsequent convection pass calculations. The Platen Interface Module determines the radiant heat absorption of the radiant walls and platens (if applicable) to establish the link between the Upper Furnace and Steam Generator Modules.

The Steam Generator Module determines heat absorption in the convective pass of the boiler. Turbine heat balance data, direct radiation absorptions, and economizer exit gas temperatures are passed automatically to this module during the iteration process. The Steam Generator Module will solve for gas and working fluid temperatures not included in the input. Conversely, given the steam and gas

temperature constraints from field test data, the module will back-calculate the heating surface areas required to make the heat balance. From this heat balance and the known heating surfaces, Surface effectiveness factors can be derived to relate the degree of fouling in the upper furnace.

The Air Heater Module predicts the performance for Ljungstrom bisector and trisector air heaters. During the boiler performance iteration, the steam temperature increase and uncorrected exit gas temperature (calculated) are passed to the Boiler Efficiency Module. The iteration is completed when the values generated in the Air Heater Module and those used in the efficiency calculation are in agreement. It should be noted that there is no provision in the model to predict the performance of the Air Preheater Parker 27 H-67-5 bisector air heaters. In this case the field data on the air heaters was used to select the Ljungstrom air heater that most closely matched the performance observed during the field tests.

3.5 BOILER PERFORMANCE PROGRAM CALIBRATION PROCEDURE

The BPP was calibrated with Jader coal field test data prior to the Island Creek coal performance calculations. The program calibration runs were made to: (1) improve the accuracy and confidence level of the BPP predictions by reducing the number of assumptions about the fireside heat transfer characteristics of the boilers and; (2) develop laboratory-to-field scale-up factors specific to Watson Unit 4. The calibration procedure began with the input of field data from Unit 4 into the BPP. These include all known temperatures, pressures and flow rates from both steam and gas sides. The BPP was then used to back-calculate, in a reverse step-by-step manner, several unknown parameters that affect boiler heat transfer and efficiency. The most

important unknown parameters include:

- Furnace gas and wall radiative properties
- Lower furnace average slag properties
- Tube surface effectiveness
- Air heater air/gas side efficiencies

The schematic logic of the calibration procedure is outlined in Figure 3.3. Once values for the above unknown parameters were determined, a comparison was drawn between field and laboratory scale furnaces.

Additional special measurements and observations were also made during the field testing at Watson Unit 4 using the same procedures used in the laboratory, as follows:

- Deposit bonding strength measurements
- Total heat flux to furnace walls (heat flux probes)
- Furnace gas temperatures (suction pyrometer)
- Optical gas temperatures

Use of the information specified above allowed direct laboratory-to-field comparisons to be made in areas typically not covered by conventional boiler instrumentation.

A comparison of the calibrated results with the experimental test data is summarized in Table 3.2. As can be seen from the Table, the model calibration was quite good. Field test data used for calibration were obtained in October and November of 1991 from available operator board instrumentation. Table 3.2 indicates whether data values were back-calculated, obtained directly from the test data sheets, or interpolated from test data. The back-calculated are those shown as "not available" from the field data. Erroneous or questionable data was replaced by interpolated values or those calculated by heat balance calculations, where appropriate.

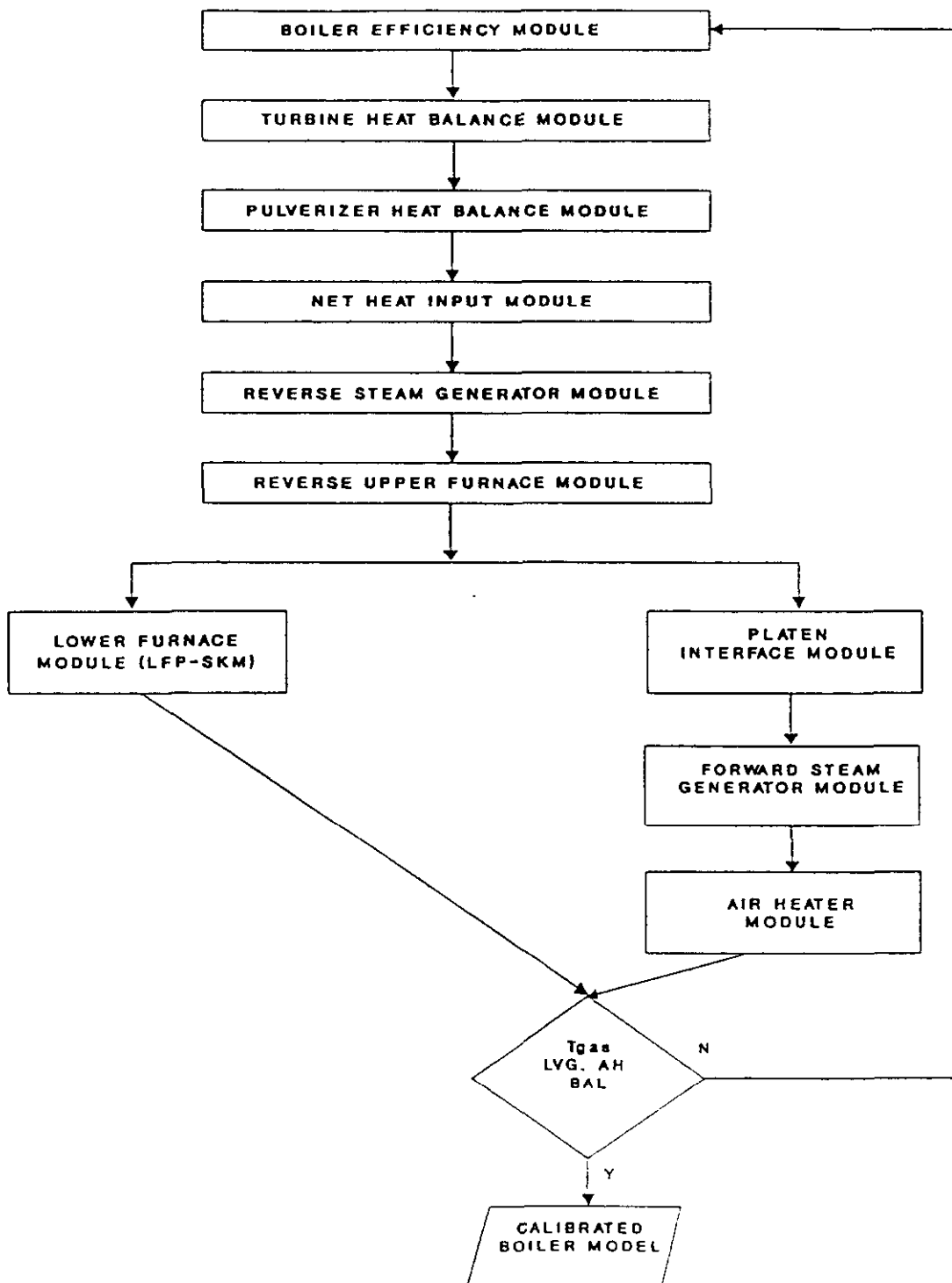


Figure 3.3 Boiler Performance Program Flowchart For Baseline Coal Calibration

Calibration of Watson Unit 4

Calibration of Watson Unit 4 firing Jader coal proceeded utilizing as much test data as possible. Generally the test data were considered to be accurate and reliable with few exceptions. The first exception was the superheat and reheat steam flow rates. In reviewing steam and water side flow rates it was noted that both superheat and reheat steam flows were not consistent with the amount of power which was produced. Therefore measured feedwater flow was compared to design flow and the ratio was applied to superheat and reheat flows.

The second exception was the horizontal furnace outlet temperature (HFOT). Only one line in the furnace outlet plane (6th floor, rear wall) was measured putting a limit on the usefulness of the data as a furnace average. The reliability of the data from the 6th floor rear wall is not supported by temperature measurements taken at both the front and rear walls on the 4th floor. See Figure 3.4 for exact location. While the measurements taken at the 4th floor only extend into the furnace a distance of 8 feet, they clearly show a bias of higher temperatures (approximately 300°F higher) toward the front wall for both Jader and Island Creek testing. See Figure 3.5 for the data as presented by Energy and Environmental Research Corp. (EER) under contract to CQE. Thus the temperatures on the front wall at the FOT plane would have probably been higher than those at the rear wall, driving the HFOT average higher. Theoretically, a multiple-shield system with a lengthy collection time is required to approach the true gas temperature. During actual testing a two-shield system was used, and due to radiation losses, the measured temperatures are most likely lower than the actual gas temperature.

The modeling program utilizes performance of Ljungstrom Bisector Air Heaters. Lacking standards for the Parker Air Heaters installed at the plant the air heaters were modeled as follows: (1) Air heater diameter was kept consistent with that installed. (2) Air heater leakage was matched with measured values. (3) Air heater depth was

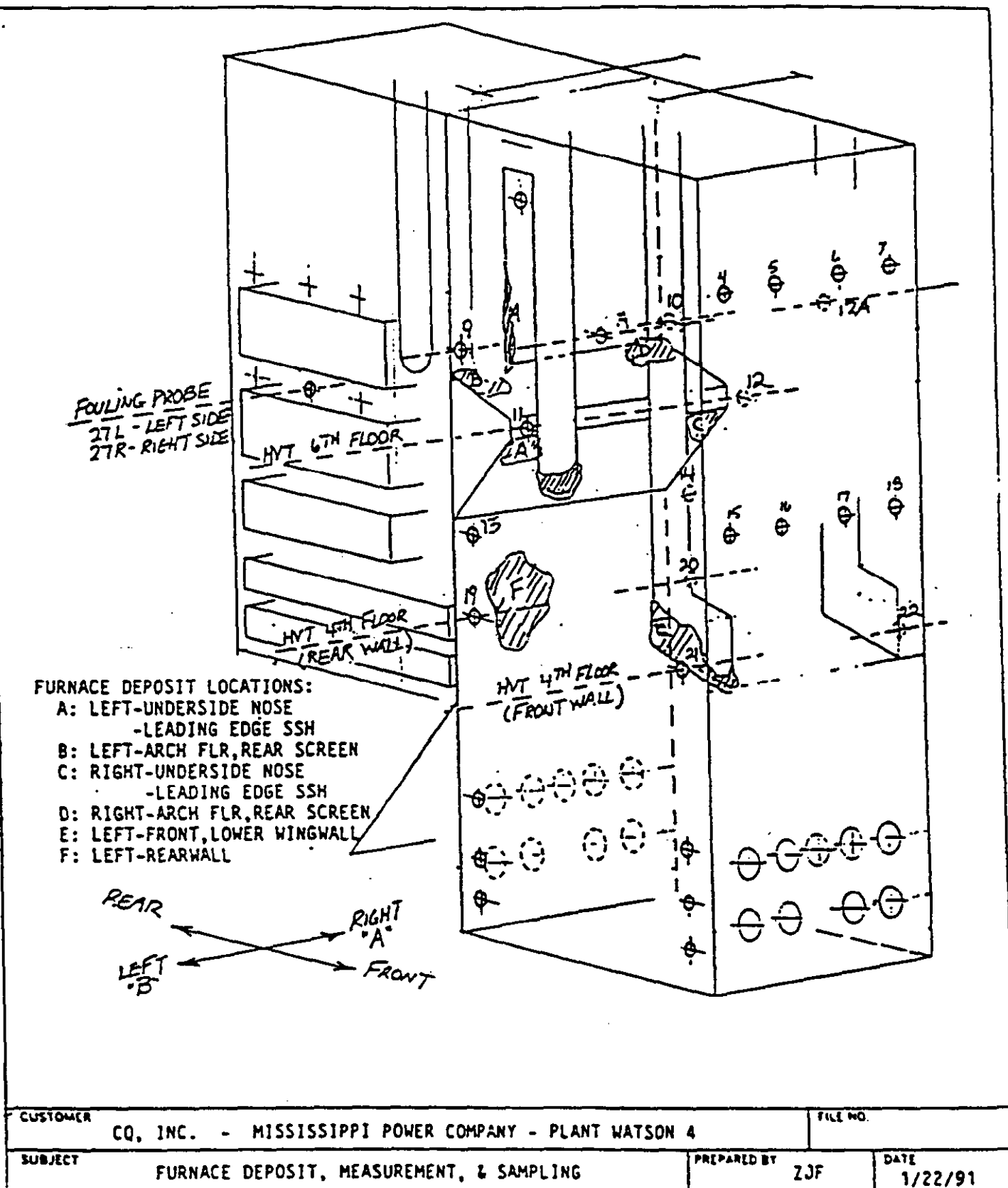


Figure 3.4 HFOT Measurement Location On Watson Unit #4

MPC: PLANT WATSON UNIT 4

FURNACE WALL GAS
CONDITIONS

TEST TRAVERSE
COMPARISON

4th FLOOR PORTS

△△△△ T13 (JADER)
●●●● T46 (ISLAND CREEK)

EER CORPORATION

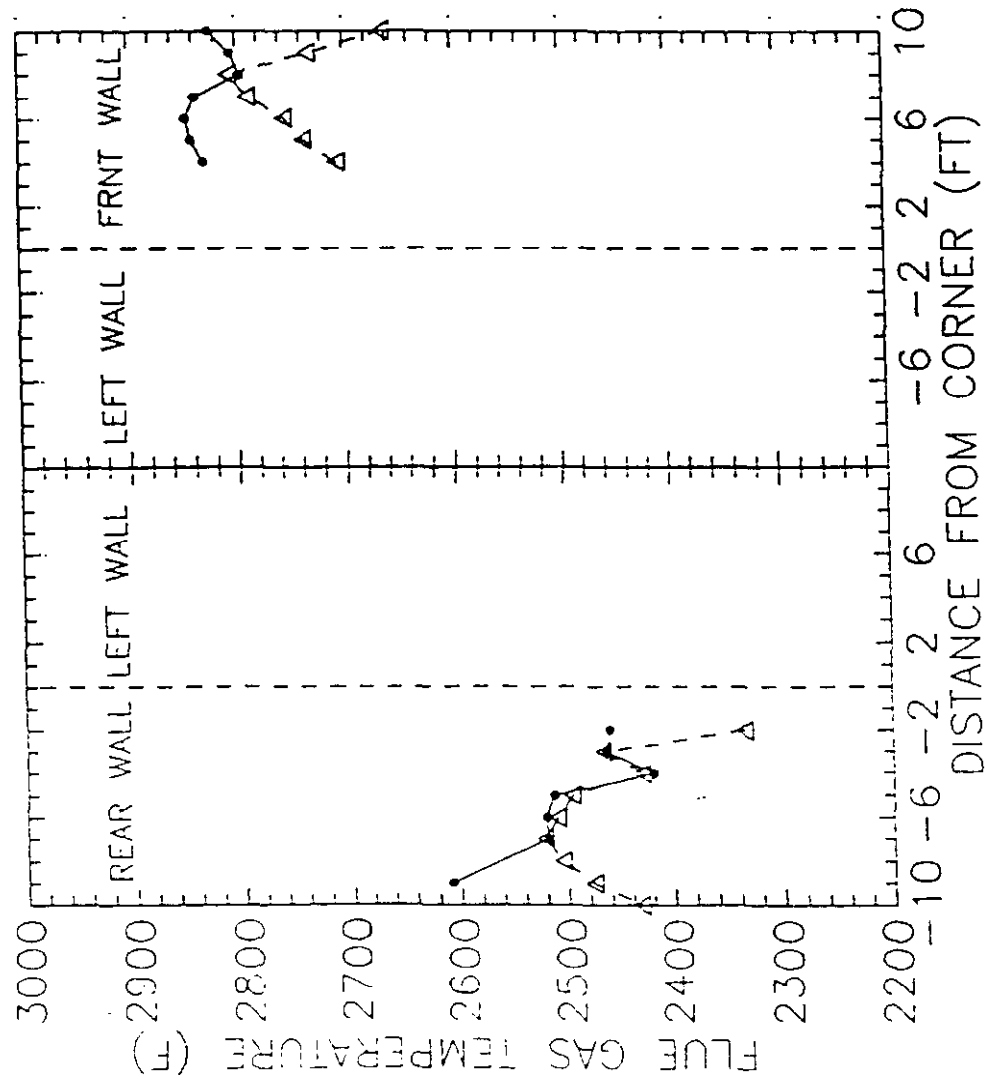


Figure 3.5 EER HFOT Data From Watson Unit #4

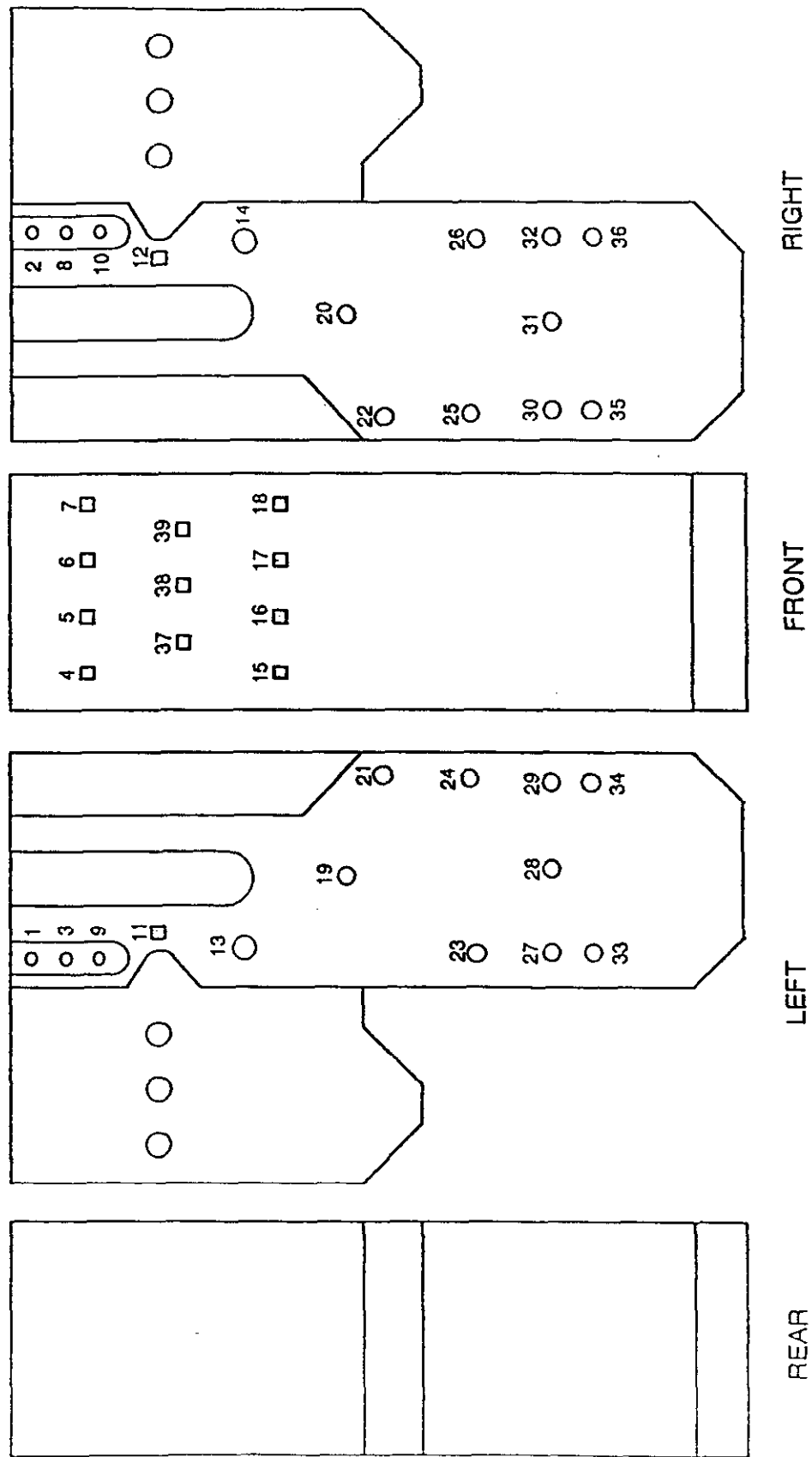


Figure 3.6 Bonding Strength Measurement Location On Watson Unit #4

Table 3.3
WATSON UNIT 4 SURFACE EFFECTIVENESS FACTORS

<u>Section Type</u>	<u>Installed Surface</u> (ft ²)	<u>Effective Surface</u> (ft ²)	<u>SEF</u>
SH High Temperature	21639	11246	.52
RH Finish 14267	10919	.77	
SH Low Temperature	35252	24987	.71
RH Low Temperature	56008	43169	.77
Economizer	46083	72492	1.57

The energy in the gas stream entering the convection pass, as well as the section absorptions, were used to back-calculate an HFOT (horizontal furnace outlet temperature). The calculated HFOT (2513°F) differed from the field measured value (2280°F) by 233°F. This difference is attributed in part to the location of the field test measurement as discussed in the previous section, i.e., the field test measurements at the HFOT plane were taken at the rear wall. Measurements taken at a lower elevation on both front and rear walls indicate a significant increase in temperature (approximately 300°F) at the front wall which would serve to drive up the average temperature at that plane. The difference is also attributed in part to the radiation losses from the thermocouple during field testing. In support of the higher back-calculated HFOT, the radiation heat flux measurements calculated in the model are in direct line with those measured in the field, as shown in Figure 3.7.

The lower furnace performance is characterized by the local thermal conductance of the deposit ($k/\Delta x$). The LFP-SKM is run in an iterative mode until the HFOT sensible heat and radiation match the field data. The major iteration variable is $k/\Delta x$. Figure 3.8 presents the thermal conductance versus local flame temperature for the FPTF Jader fuel data and the back-calculated $k/\Delta x$ values from field data, calculated from the burner zone up through the furnace outlet plane. The $k/\Delta x$ back-calculated for the

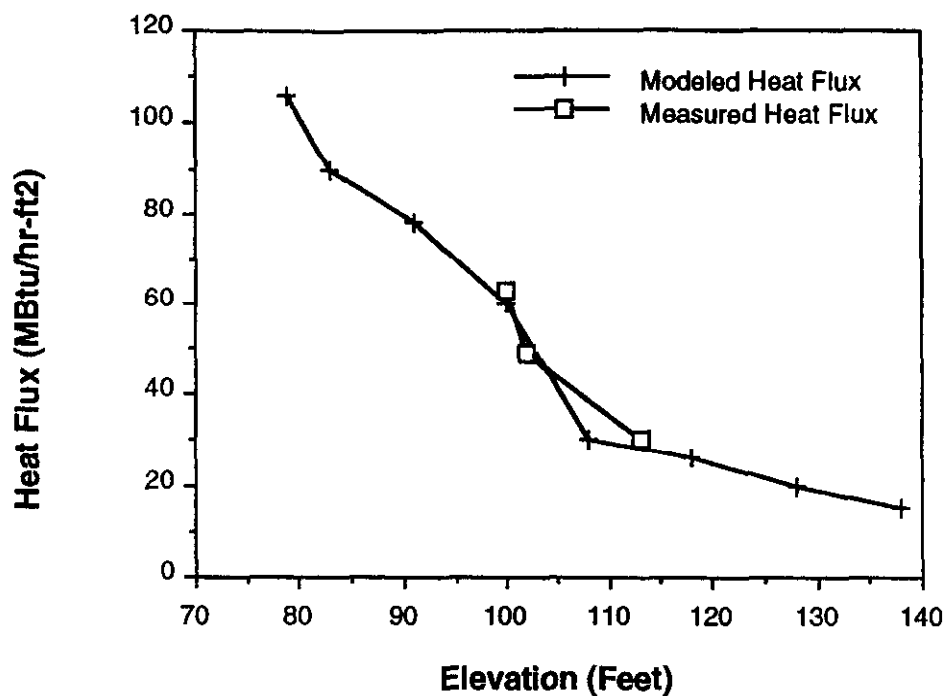


Figure 3.7 Radiation Heat Flux
Watson Unit 4

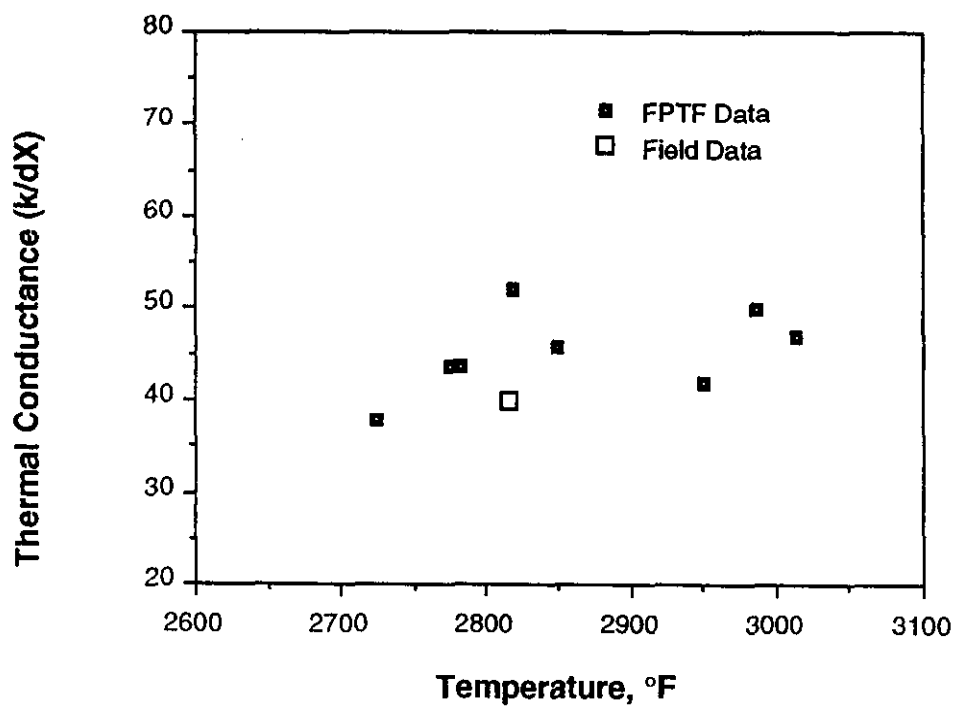


Figure 3.8 Thermal Conductance vs. Flame Temperature
Jader Coal

Jader Coal was 40. Based on the good agreement between the field and the FPTF, correlations were considered unnecessary for scale-up purposes.

3.6 BOILER PERFORMANCE WITH ISLAND CREEK COAL

Performance Prediction Procedure

Generally, the approach to predicting boiler performance has been fundamentally based on bench- and pilot-scale data. Bench and pilot-scale performance "indicators" provided relative comparisons of the Jader and Island Creek coal behavior in seven major areas: abrasion, pulverization, combustion, ash slagging, ash fouling, ash erosion, and gaseous emissions. The coal quality performance indicators have been derived from the laboratory results in each of these areas and are presented in Table 3.4. The indicators included conventional ASTM coal analysis indices (base/acid ratio, ash fusion temperature, etc.), the special parameters developed from the FPTF and the special bench-scale-derived indices. The ASTM indices were calculated primarily as familiar reference points which are widely understood in the utility industry. However, recent investigations have shown them to have limited reliability in their prediction of coal quality and its relationship to utility steam generator performance. Use of special bench-scale indices and FPTF-derived data in conjunction with the boiler performance model has provided results which agree quite well with field data and can be used to predict performance under altered firing conditions.

Each of the coal quality indicators was employed in one of the following three ways: 1) direct input to the BPP model, 2) direct input to existing empirical correlations, or 3) capacity and operating limits for the boiler island equipment. All other indicators were evaluated on a comparative basis to establish the relative quality of the test coals. Differences between coal quality indicators for the Jader coal and indicators for the Island Creek coal dictated what adjustments needed to be made to the coal-quality-related inputs.

The performance of Watson Unit 4 firing the Island Creek Coal was predicted with the model as outlined in Figure 3.9. The criteria used for the temperature and capacity

Table 3.4
BENCH AND PILOT-SCALE COAL QUALITY INDICATORS

<u>Indicator</u>	<u>Test</u>	<u>Jader Coal</u>	<u>Island Creek Coal</u>
<u>Abrasion</u>			
Ash Content, %MF	ASTM	8.83	6.91
Total Quartz, %	Special	30.0	21.7
<u>Pulverization</u>			
Hardgrove Index	ASTM	62.25	52.50
Coal HHV, Btu/lb MF	ASTM	13426	13381
Relative Grinding Energy KW/MBtu	FPTF	0.542	0.610
<u>Combustion</u>			
Carbon in Ash, %	FPTF	0.7	0.8
Carbon Conversion, %	FPTF	99.9	99.9
<u>Ash Slagging</u>			
Base/Acid Ratio (B/A)	ASTM	0.40	0.45
Slagging Index (B/A x % Sulfur)	ASTM	1.09	1.28
Fe ₂ O ₃ in Ash, %	ASTM	21.00	21.09
Max. Gas Temp. for Sootblower Effectiveness, °F	FPTF	3110	3010
<u>Ash Fouling</u>			
Fouling Index (B/A x % Na ₂ O)	ASTM	0.15	0.36
Na ₂ O + K ₂ O in Ash, %	ASTM	2.42	2.88
Max. Gas Temp. for Sootblower Effectiveness, °F	FPTF	2500*	2400*
Deposit Buildup Rate/Sootblowing Frequency, h	FPTF	6	10
<u>Erosion</u>			
SiO ₂ + Al ₂ O ₃ in Ash, %	ASTM	61.48	64.68
Erosion Rate (mil/10 ⁴ hr)	FPTF	0.60	0.48

* Extrapolated from the highest temperatures attained in the superheater section during testing

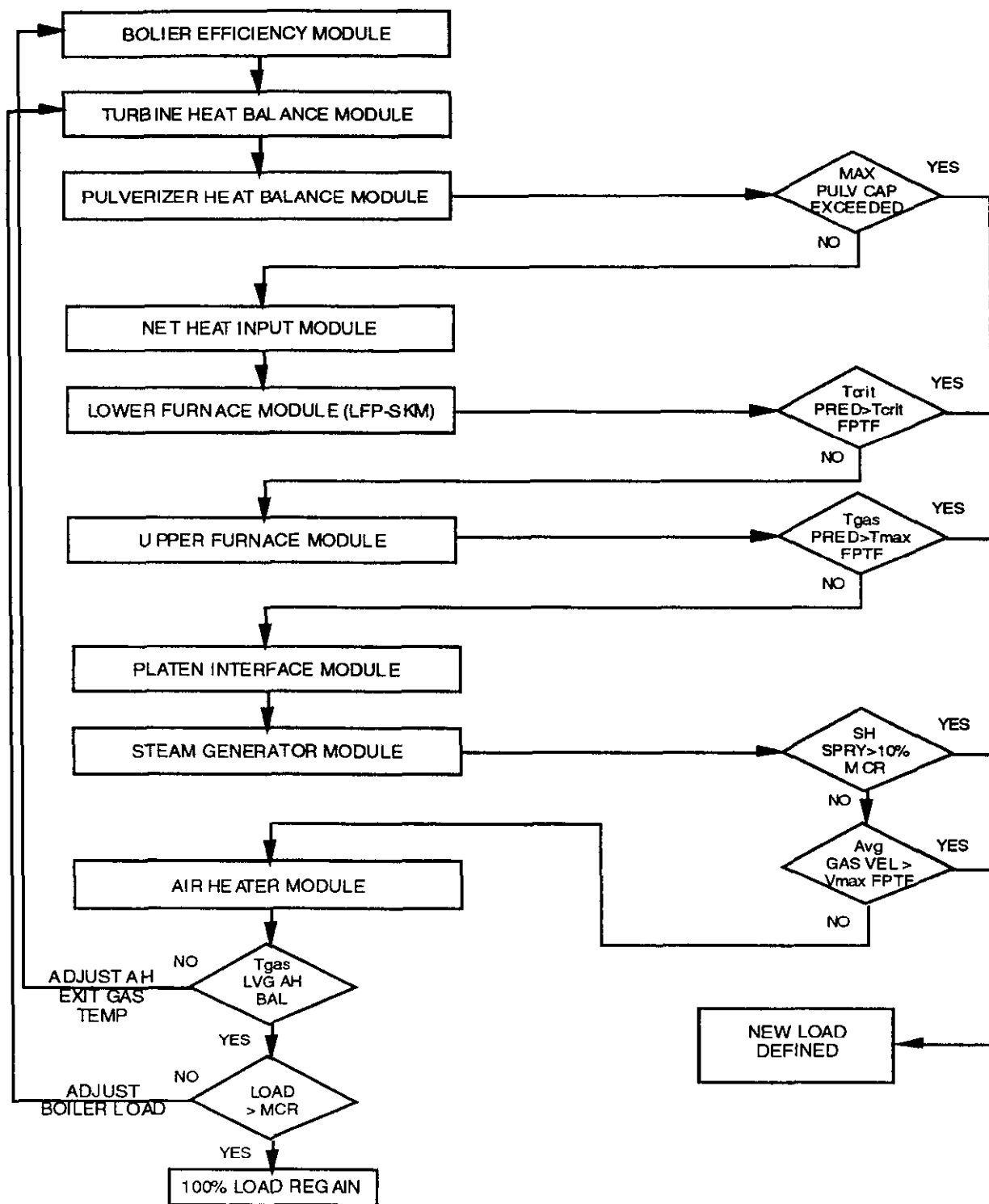


Figure 3.9 Boiler Performance Program Flowchart For Perf. Prediction

limits for firing the coals in the boiler were as follows:

- Maximum Furnace Temperature, °F

<u>Fuel</u>	<u>Temp.</u>
Jader	3110
Island Creek	3010

- Maximum Convection Pass Temperature*, °F

<u>Fuel</u>	<u>Temp.</u>
Jader	2500
Island Creek	2400

* These are the maximum temperatures for cleanable deposits in the convection pass during testing in the FPTF.

The plant utilizes three Riley Ball Tube Mills to pulverize the coal. Due to the lack of performance curves for the Riley mills, the pulverizers were not modeled for calibration purposes.

Lower furnace slagging potential was incorporated into the modeling process by using the maximum furnace temperature data and the effective thermal conductance ($k/\Delta x$) from the FPTF. Data from previous testing indicates that the laboratory critical furnace temperature data can be applied in the model with a 100°F correlation factor (i.e., Jader fuel had an FPTF critical temperature of 3010°F, while in the field unit this would correlate to a 3110°F average slice temperature model prediction). Lower furnace gas temperatures above the peak flame temperature would probably cause deposits to be unremovable and exhibit a lower $k/\Delta x$ value, creating a higher resistance to the transfer of heat from the gas to the water side. Gas temperatures would then be higher than normal, possibly causing slag carry-over into the upper furnace area. The $k/\Delta x$ used for the Island Creek Coal was 40, as presented in Figure 3.10. These limits were incorporated into the model to portray the effects of the coal ash deposit on the lower furnace walls.

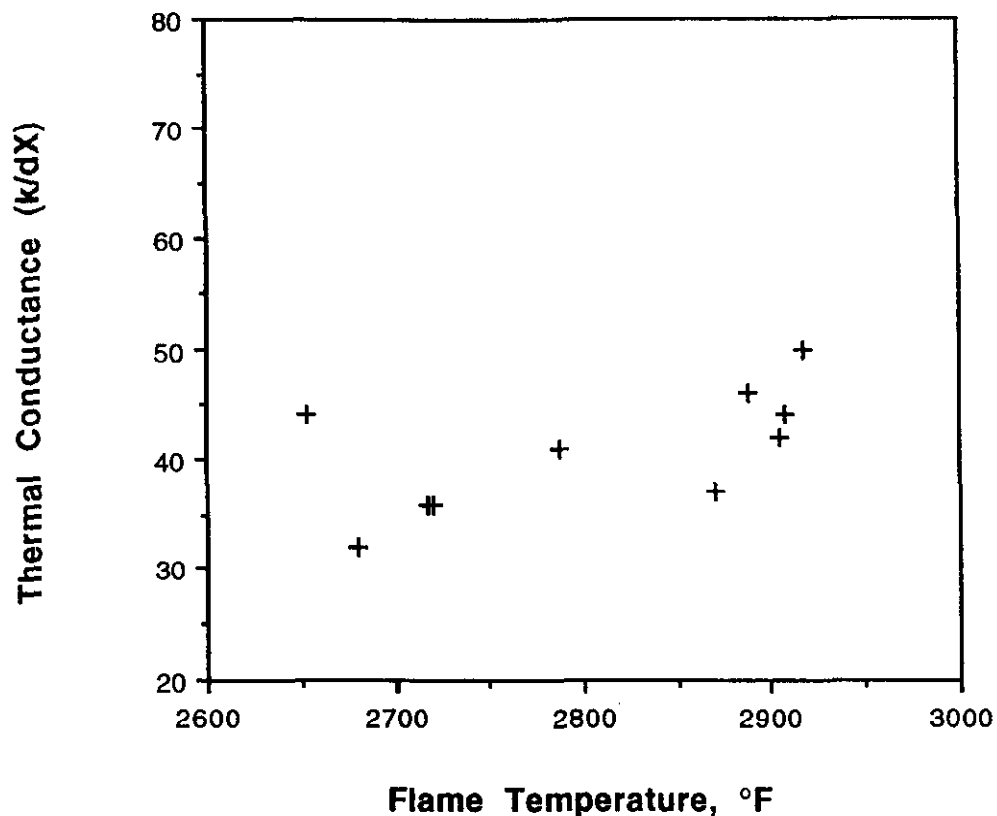


Figure 3.10 Thermal Conductance vs. Flame Temperature

Island Creek Coal

The Jader coal demonstrated low convection section fouling performance in the FPTF at gas temperatures up to 2420°F and data indicates controllable deposits up to 2500°F. The Jader coal calibration for the bonding strength/local gas temperature relationship indicated that the laboratory data could be directly applied. Therefore, the maximum allowable convective gas temperature was established at 2500°F for the Jader coal. Backpass temperature fouling limitations were similarly set at 2400°F for the Island Creek coal. Above these limits, uncontrollable fouling was possible. In the field, uncontrollable fouling causes a progressive rise in backpass temperatures,

which can ultimately lead to metal overheating and possible tube failures. Excessive fouling can also cause partial blockages of the gas pass.

Fly ash erosion rates were established for both the Jader and Island Creek coals. The measured rate during FPTF testing was 0.48 mils/10,000 hr for the Jader coal and 0.60 mils/10,000 hrs for the Island Creek coal at a velocity of 60 ft/sec. It is generally considered that an erosion rate of 2.0 mils/10,000 hrs is the maximum allowable rate from a design standpoint. Erosion in excess of this value does not normally affect boiler performance but can contribute to increases in boiler maintenance costs. Erosion rate was therefore not a boiler performance-limiting factor.

Comparison of Baseline Calibration And Alternate Performance Projection

A comparison of baseline calibrated results (Jader coal) versus a performance projection utilizing the alternate coal (Island Creek) was conducted by entering the alternate coal ASTM analyses, along with FPTF data in the BPP while retaining the baseline calibrated factors. After entering these parameters, the program utilizes the baseline calibrated data and iterates until an acceptable solution is reached. Results are summarized in Table 3.5.

Boiler island performance of the Island Creek coal was compared to the Jader coal at an equivalent heat duty. Main and reheat steam flows and pressures were held constant while the coal feed rate and steam outlet temperatures were allowed to vary to achieve similar air heater outlet temperatures. The boiler island performance analysis is based upon the present wall blower and retractable soot blower operation and coverage in Unit 4 and interpretation of FPTF results. Analyses indicate that superheater and reheater performance will be acceptable, with the present firing condition.

Table 3.5
WATSON UNIT 4 ISLAND CREEK COAL PERFORMANCE RESULTS

	Jader Baseline Calibration	Island Creek Performance Projection
<u>General Data</u>		
Excess Air (@ Econ Out), %	19.7	19.7
Elevations in Service	3	3
Boiler Efficiency, %	89.35	88.36
Boiler Capacity, MW	255.	255.
<u>Steam and Water Flows, 10³ LB/H</u>		
Feedwater	1685.	1685.
Main Steam	1668.	1668.
Reheat Steam	1469.	1469.
<u>Boiler Fluid Temp/Press, °F/PSIG</u>		
Feedwater	467./2573.	467./2573.
Economizer Outlet	571./2518.	573./2518.
Low Temp SH Inlet	670./2511.	670./2511.
Wingwall Inlet	720./2480.	722./2480.
SH Platen Inlet	756./2453.	756./2453.
SH Finishing Inlet	939./2402.	942./2429.
SH Finishing Outlet	966./2402.	969./2402.
Low Temp RH Inlet	602./ 520.	602./ 520.
RH Finishing Inlet	783./ 500.	786./ 500.
RH Finishing Outlet	992./ 490.	999./ 490.
<u>Furnace Performance</u>		
Net Heat Input, MBtu/Hr	2313.	2338.
NHI/PA, MBtu/Hr-Ft ²	1.82	1.84
Furnace Outlet Temperature, °F	2513.	2517.
Convection Pass Inlet Temp, °F	2140.	2145.
Economizer Outlet Temperature, °F	756.	759.
<u>Air Heater Performance</u>		
Ambient Air Temperature, °F	78.5	78.5
Air Inlet Temperature, °F	89.5	89.5
Air Outlet Temperature, °F	595.	613.
Gas Inlet Temperature, °F	755.	759.
Gas Outlet Temperature, °F	277.	291.
Air Side Efficiency	.761	.782
Gas Side Efficiency	.664	.641

Boiler efficiency decreased from 89.35 % for the Jader coal to 88.36 % for the Island Creek coal. This difference can be attributed to the higher moisture in the fuel and the necessity to raise the air temperature leaving the economizer in order to close the unit heat balance. It should be kept in mind that the air heater was sized based on Ljungstrom standards utilizing the baseline test. Leakage corrections utilized for the baseline tests were kept constant for the alternate performance run. Pulverizer performance was not evaluated using the model due to the lack of standards for Riley Tube mills.

The Watson Unit 4 boiler should be capable of its typical cycling operation with the Island Creek coal. The main limiting factor in maintaining load is the wall blower effectiveness and coverage. The maximum furnace temperature as defined by field correlations with the FPTF data is 3010°F. The peak flame temperature as determined in the modeling procedure is 3001°F. Therefore a 9°F differential exists between the operating peak flame temperature and the critical temperature. Provided that the wall blowers are maintained in good operating condition, the critical peak flame temperature would not be exceeded.

The average thermal conductance (as determined from FPTF data) for the Island Creek coal was 40 Btu/hr-ft²°F. If wall blower frequency is increased and cleaning is made more effective in the lower furnace, the superheater performance could become marginal. As wall blower effectiveness increases, lower furnace cleanliness increases, resulting in higher thermal conductances and greater heat absorption through the waterwalls. This will lower furnace outlet gas temperatures and reduce energy available for absorption in the final superheater section, which already requires no spray. All other data seemed to fall within acceptable ranges showing the Island Creek Coal as an acceptable fuel from a performance standpoint.

Evaluation of Full-Scale and Pilot-Scale Data for Island Creek Coal

In assessing the impact of firing the Island Creek coal, the boiler island performance is projected from the data provided by bench-scale and pilot-scale testing. Both the Jader and Island Creek coals were field tested at Watson Unit 4. The usefulness and validity of employing bench- and pilot-scale data can be evaluated relative to the fuel's actual performance in the commercial unit. The results of each evaluation can also be used to extend the existing data base for predicting fuel slagging and fouling performance.

Results for the Island Creek coal are presented in Table 3.6. The first column lists the actual field test data; the second lists the "calibrated" test data based upon ASTM and FPTF tests on the Island Creek coal; the last lists the performance predictions based on the Jader coal calibration. The calibrated field test data and the performance projection values are reasonably close. The results presented in Table 3.7 were expected based on the differences in unit operation. The Jader detailed characterization tests were conducted at 255 MW(g), while the Island Creek tests were conducted at 250 MW(g). This decrease in MW(g) production occurred due to limitations caused by the FD fan and the generally "wetter" slag consistency observed with the Island Creek coal. The reduced load caused a drop in steam flows while the fan restrictions caused a decrease in excess air levels (19.7% to 16.0%). The decrease in excess air generally promotes a favorable environment for slagging and was further enhanced by the nature of the Island Creek coal as supported by results from FPTF testing. The differences in operation then were generally due to the effects of mass flow (gas and steam side) and surface effectiveness factors (SEF's). Surface effectiveness factors decreased for the Island Creek testing in the economizer section by an average 8.9%, remaining similar in other areas (see Table 3.8). The change in the economizer section SEF is supported by the visual observations in that section showing bridging of deposits during Jader testing and the relatively clean tubes during Island Creek testing. The reduced heat transfer during the Jader testing is further supported by the higher-deposit build-up rate during the Jader testing in the FPTF.

Table 3.6
WATSON UNIT 4 ISLAND CREEK COAL PERFORMANCE RESULTS

	Field Test Data	Reverse Calibration	Performance Projection
<u>General Data</u>			
Excess Air (@Econ Out), %	16.0	16.0	19.7
Elevations in Service	3	3	3
Boiler Efficiency, %	88.54	88.54	88.36
Boiler Capacity, MW	250.	250.	255.
<u>Steam and Water Flows, 10³ LB/H</u>			
Feedwater	1599.	1599.	1685.
Main Steam	—	1583.	1668.
Reheat Steam	—	1394.	1469.
<u>Boiler Fluid Temp/Press, °F/PSIG</u>			
Feedwater	463./2566.	463./2566.	467./2573.
Economizer Outlet	577./2512.	564./2514.	573./2518.
Low Temp SH Inlet	—/—	669./2506.	670./2511.
Wingwall Inlet	—/—	718./2471.	722./2480.
SH Platen Inlet	757./—	757./2440.	756./2453.
SH Finishing Inlet	—/—	926./2413.	942./2429.
SH Finishing Outlet	997./2380.	997./2380.	969./2402.
Low Temp RH Inlet	621./ 500.	621./ 500.	602./ 520.
RH Finishing Inlet	—/—	800./ 477.	786./ 500.
RH Finishing Outlet	1002./470.	1002./ 470.	999./ 490.
<u>Furnace Performance</u>			
Net Heat Input, MBtu/Hr	—	2255.	2338.
NH/PA, MBtu/Hr-Ft ²	—	1.78	1.84
Furnace Outlet Temperature, °F	2377.	2573.	2517.
Convection Pass Inlet Temp, °F	—	2170.	2145.
Economizer Outlet Temperature, °F	759.	759.	759.
<u>Air Heater Performance</u>			
Ambient Air Temperature, °F	69.	69.	78.5
Air Inlet Temperature, °F	89.	89.	89.5
Air Outlet Temperature, °F	609.	609.	613.
Gas Inlet Temperature, °F	759.	759.	759.
Gas Outlet Temp Corr., °F	278.	295.	291.
Gas Outlet Temp Uncorr., °F	324.	334.	—
Air Heater Leakage, %	19.82	19.79	—
Air Side Efficiency	—	.777	.782
Gas Side Efficiency	—	.635	.641

Table 3.7
DATA SUMMARY FOR THE ISLAND CREEK COAL

<u>Boiler Operating Parameters</u>	<u>Reverse Calibration</u>	<u>Performance Projection</u>	<u>Percent Difference</u>
Boiler Efficiency, %	88.54	88.36	.20
SH Outlet Temperature, °F	997.	969.	2.80
RH Outlet Temperature, °F	1002.	999.	.30
Furnace Outlet Temperature, °F	2573.	2517.	2.17
Economizer Outlet Temperature, °F	759.	759.	.00

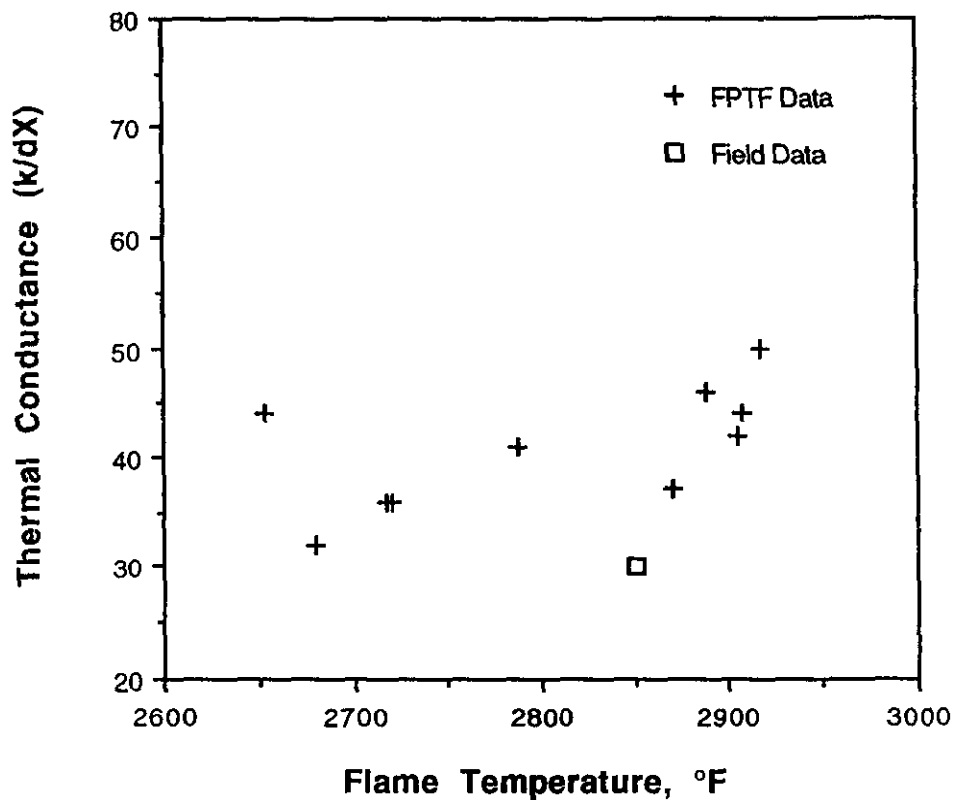
Table 3.8
WATSON UNIT 4 SURFACE EFFECTIVENESS FACTORS

<u>Section Type</u>	<u>Installed Surface (ft²)</u>	<u>Jader SEE</u>	<u>Island Creek SEE</u>
SH High Temperature	21639	.52	.56
RH Finish	14267	.77	.78
SH Low Temperature	35252	.71	.70
RH Low Temperature	56008	.77	.78
Economizer	46083	1.57	1.43

Results from the pilot-scale testing indicate that the average $k/\Delta x$ was 40 Btu/hr-ft² for the Island Creek coal. Back calculated values from the field data give the thermal conductance a value of 30 Btu/hr-ft² (See Figure 3.11). The higher steam flows used from the Jader calibration in combination with the higher thermal conductance ($k/\Delta x$ obtained from FPTF testing) caused more heat to be absorbed in the lower furnace resulting in a reduced furnace outlet temperature and ultimately a lower superheater outlet temperature for the performance projection based on the Jader calibration.

3.7 FIELD AND PILOT-SCALE CORRELATION UPDATE

In addition to providing intermediate results for the lower furnace (i.e. peak furnace temperatures and $k/\Delta x$), it has also been a goal of this program to make use of the



**Figure 3.11 Thermal Conductance vs. Flame Temperature FPTF vs. Field
Island Creek Coal**

information obtained under previous programs (sponsored by EPRI) to improve the correlations between the pilot-scale and field test data. Based on the fuels that were both pilot-scale tested and field tested a more accurate correlation is available for using the $k/\Delta x$ obtained during pilot-scale testing, in future performance evaluations (See Figure 3.12).

The correlation for the $k/\Delta x$ parameter is still a linear one. The slope of the curve is still 1.0, but the y-intercept has shifted up by 2.25. The data points fall in a fairly tight band except for the Northeastern Unit 4 70% WY/30% OK point, which was not

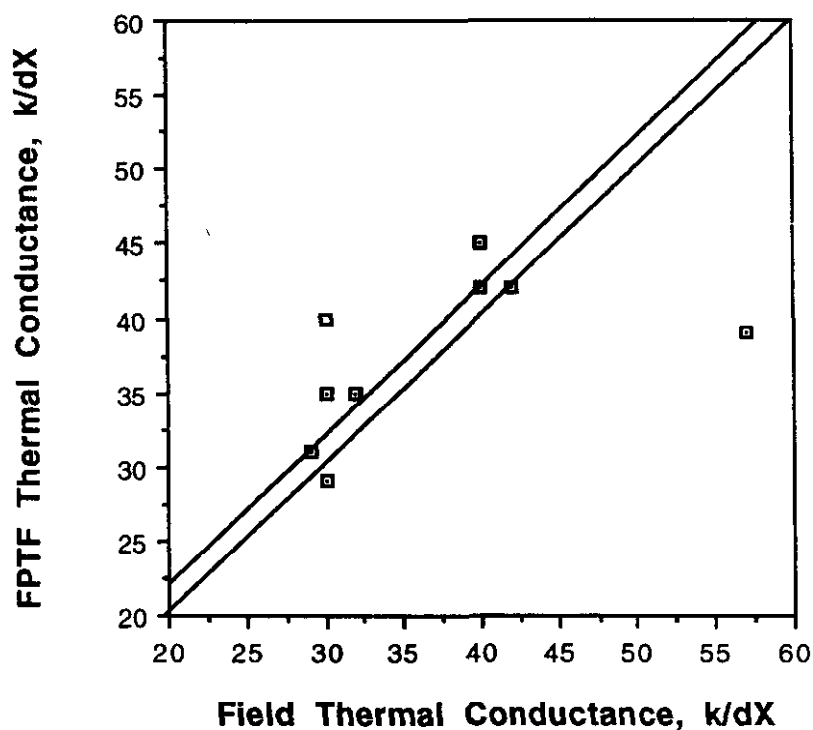


Figure 3.12 FPTF vs. Field Thermal Conductance Correlation

included in the correlation due to the extreme shift in field test boiler operating conditions. During that particular test the wall blowers were run continuously, a steady state "dirty" condition was never allowed to develop as for all the other points on the graph as well as for the pilot-scale tests. All of the data points values and coal/unit identification are listed in Table 3.9.

ABB CE BENCH-SCALE FACILITIES

Drop Tube Furnace System-1 (DTFS-1)

The Drop Tube Furnace System-1 (Figures A-1 and A-2) is comprised of a 1-inch inner-diameter horizontal-tube gas preheater and a 2-inch inner-diameter vertical-tube test furnace for providing controlled temperature conditions. Both tubes are electrically heated with silicon carbide elements (SiC) and are rated at 2800°F.

The principle of operation of the DTFS is as follows: Size-graded fuel is introduced with a small amount of carrier gas into the hot reaction zone of the test furnace through a water-cooled fuel injector. A pre-heated secondary gas stream is introduced around the primary stream. Injection of fuel particles into the hot gas stream results in a rapid heating of the particles to the prevailing gas temperature (at rates greater than 10^4 °C/sec.). Following the rapid heating period, pyrolysis, gasification and/or combustion of particles occur for a specific time. Then all reactions are rapidly quenched in a water-cooled sampling probe. Solid products are separated from the gaseous products in a small filter housing, and an aliquot of the effluent gas sample is sent to a pre-calibrated gas analysis system for on-line determination of NO_x, SO₂, O₂, CO₂, CO and THC (total hydrocarbons) concentrations using the principles given in Table A-1. A Data Acquisition System (DAS) records, on demand, all relevant test data for subsequent retrieval and processing.

The solid products collected at various locations along the axis of the DTFS-1 reaction zone can be analyzed to determine solid conversion efficiencies. An ash tracer method, which is based on the assumption that ash remains inert during combustion, is used to calculate the fuels' pyrolysis, gasification or combustion efficiencies.

Flammability Index Apparatus

The Flammability Index Apparatus (Figure A-3) is a device used to determine the ignition temperatures of pulverized solid fuels under specific conditions. About 0.2 g of sample sized to 200x0 mesh is placed in a sample holder. The furnace is preheated to a desired temperature, then a solenoid-operated valve is opened, allowing oxygen from a 2-liter storage reservoir to suspend and convey the sample through the

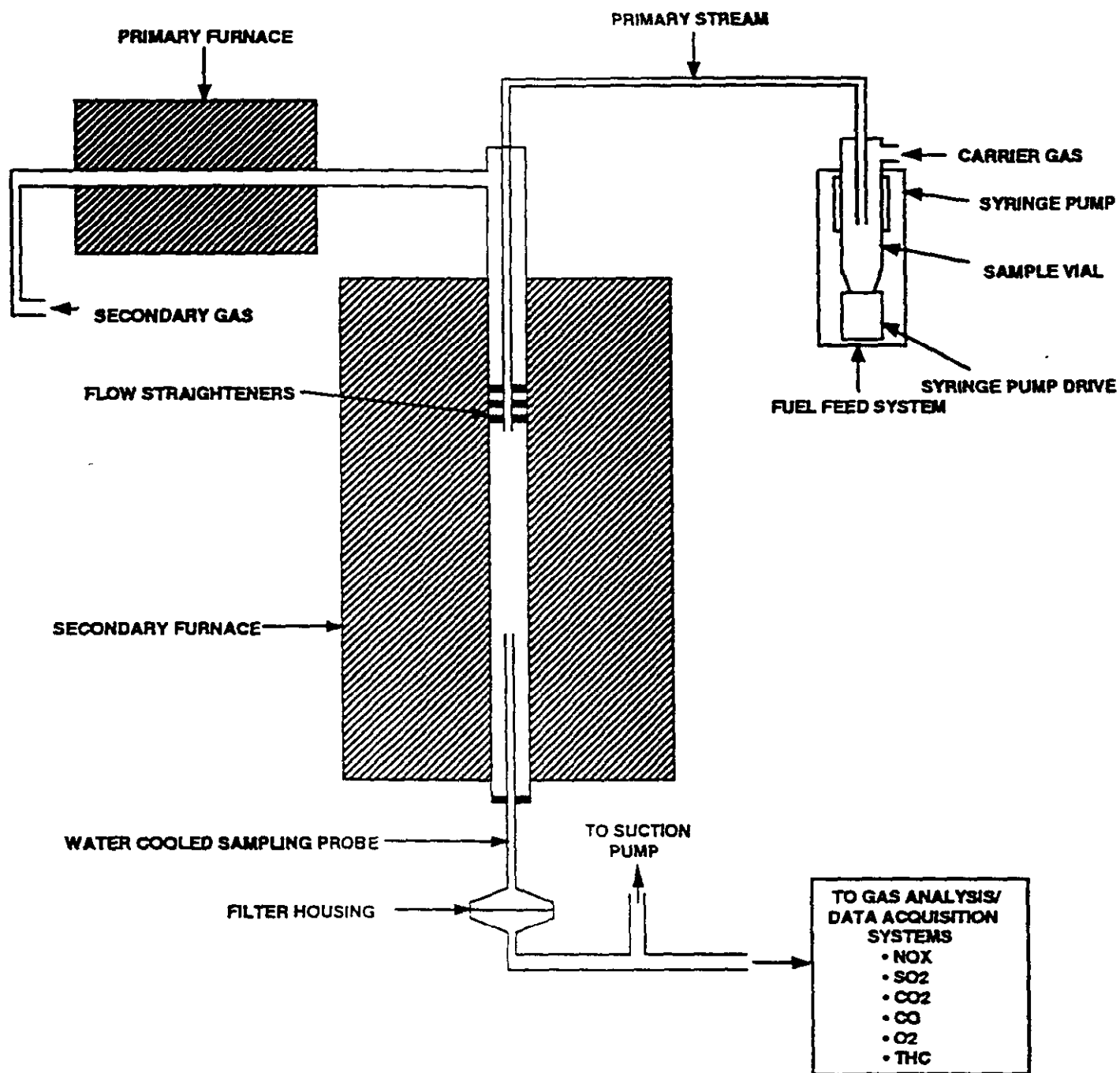


Figure A.1 Schematic of Drop Tube Furnace System (DTFS-1)

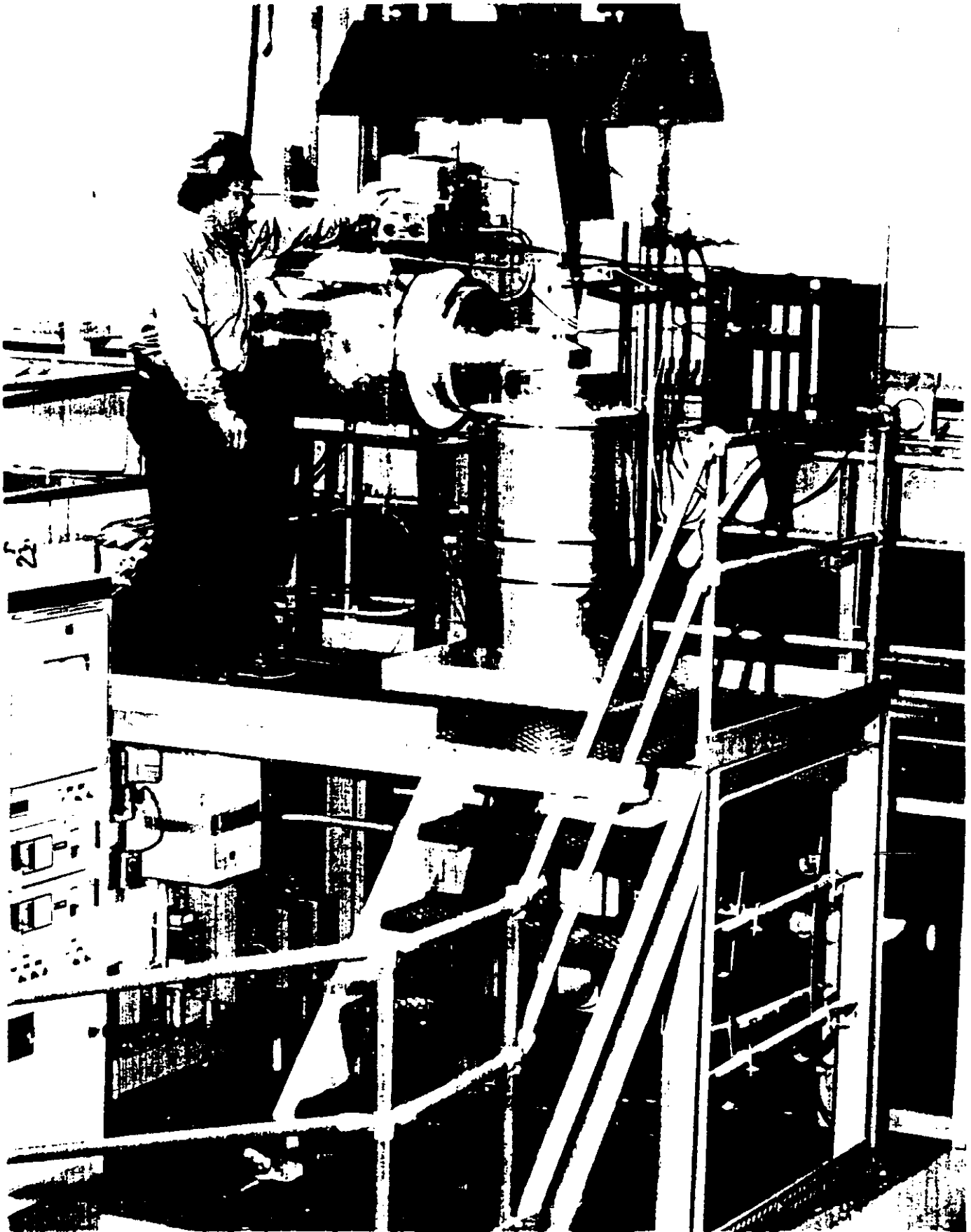


Figure A.2 Overview of Drop Tube Furnace System



Figure A.3 Flammability Apparatus

furnace. If ignition does not occur, the procedure is repeated at higher temperatures, in 50 °F increments, until ignition occurs. If ignition does

Table A-1
**DIAGNOSTIC EQUIPMENT ASSOCIATED WITH
THE DROP TUBE FURNACE SYSTEM**

COMPONENT	PRINCIPLE	ANALYZER
Nitrogen Oxides (NO _x)	Chemiluminescence	Thermo-Electron Model 10AR
Oxygen (O ₂)	Fuel Cell	Teledyne Model 326A
Sulfur Dioxide (SO ₂)	Photometric	DuPont Instruments Model 400 :
Carbon Monoxide (CO)	IR Spectroscopy	IR Industries Model 703-021
Carbon Dioxide (CO ₂)	IR Spectroscopy	IR Industries Model 702-074
Total Hydrocarbons (THC)	Flame Ionization	Beckman Model 400A

occur in the first trial, then the procedure is repeated to determine the temperature below which ignition does not occur. In either case, fine tuning is necessary to further narrow the error margin. This ignition temperature is called the Flammability Index. The value of the Flammability Index compared to other fuels indicates the ignition temperature/flame stability on a relative basis.

TGS-2 Thermo-Gravimetric Analysis System

The Perkin-Elmer Model TGS-2 (Figure A-4) is a complete, second-generation system for accurately recording the weight loss or weight gain or rate of weight change of a sample as it is subjected to a precisely controlled temperature environment. It is a completely modular system consisting of the following independently packaged units:

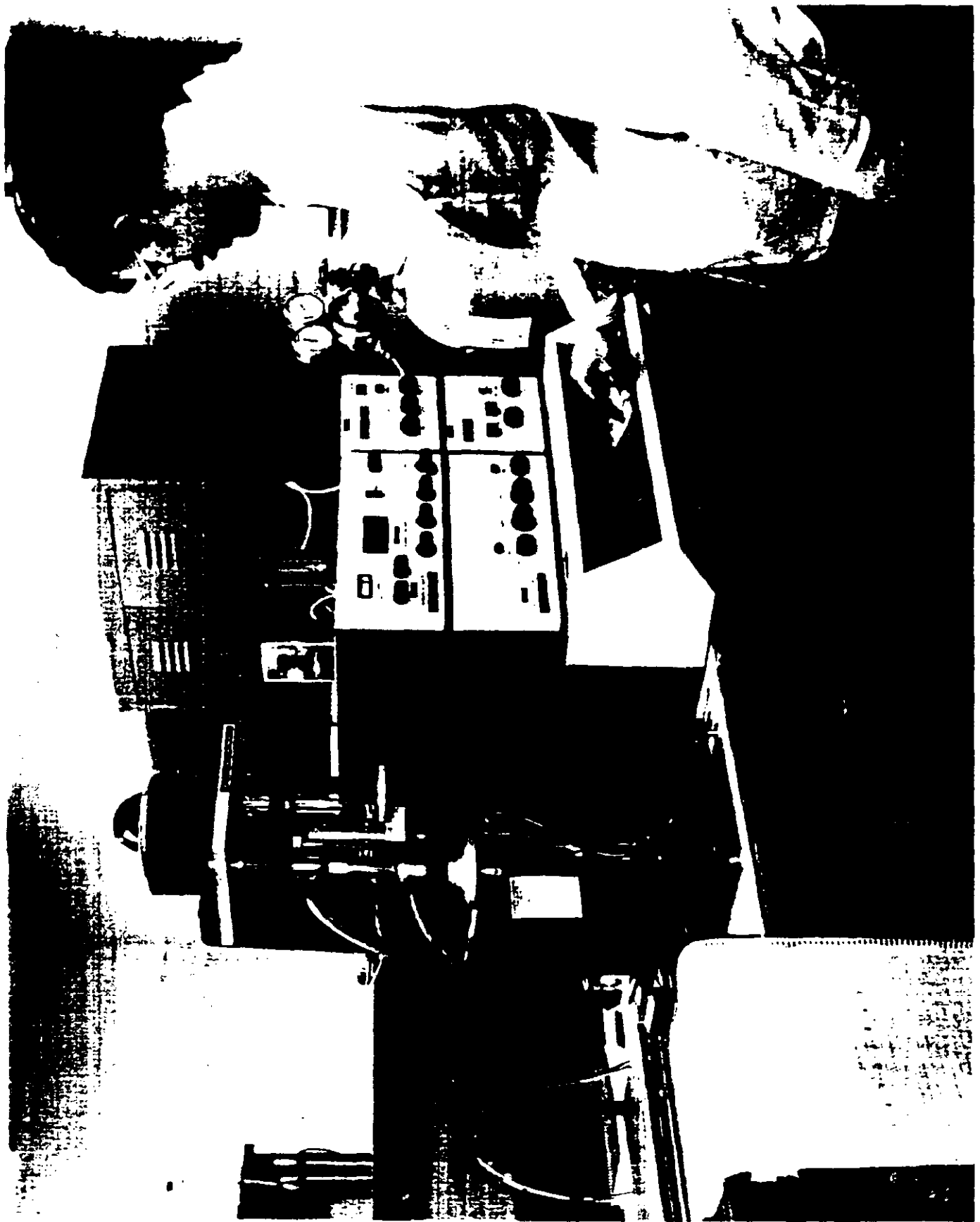


Figure A.4 Thermo-Gravimetric Analysis System

the Thermo-balance Analyzer, the Electronic Balance Control, the programmable Temperature Microprocessor Controller, the Heater Control Unit, the First Derivative Computer (FDC), and the Recorder.

This apparatus uses a small solid sample to determine either its micro-proximate analysis using the general procedure established by the American Society for Testing and Materials (ASTM) or its thermo-gravimetric reactivity under specific experimental conditions (heating rate, reaction medium, and reaction temperature).

The micro-proximate analysis is determined as follows: A 4-6 mg sample is purged with nitrogen to remove trace oxygen. The moisture loss is obtained by heating in nitrogen to 105°C and holding for three minutes. Subsequently, the sample is heated at 100°C/min to 950°C and held at this temperature for five minutes to determine volatile matter content. After this, the temperature is lowered to 750°C and a switching valve is used to introduce oxygen for the combustion of fixed carbon at this temperature. The residue represents the ash content.

The isothermal char reactivity test is determined as follows: A 4-6 mg sample of specific size grade is placed in the TGS-2 System and heated in the presence of nitrogen at 50°C/min to the reactivity temperature (700°C). After stabilization at this temperature, the reaction medium (air) is introduced. The percent weight of the unburned char and rate of weight loss are recorded on a strip chart as a function of time. These thermo-grams are subsequently used to determine the char combustion efficiency history and reactivity parameter (which indicates the maximum rate of weight loss per unit weight of the original sample in the TGS-2 System).

Quantasorb Surface Area Analyzer

The principle of operation of the Quantasorb Surface Area Analyzer (Figure A-5) involves passing a mixture of helium (used as a carrier) and adsorbate (N₂ or CO₂) through a small, U-shaped cell containing the dry sample (i.e., out-gassed a priori in the Quantasorb for one hour at 200 °C using nitrogen as the sweeping gas). The amount of adsorbate physically adsorbed at various partial pressures on the sample (adsorbent) surface can then be used to calculate the sample's surface area.

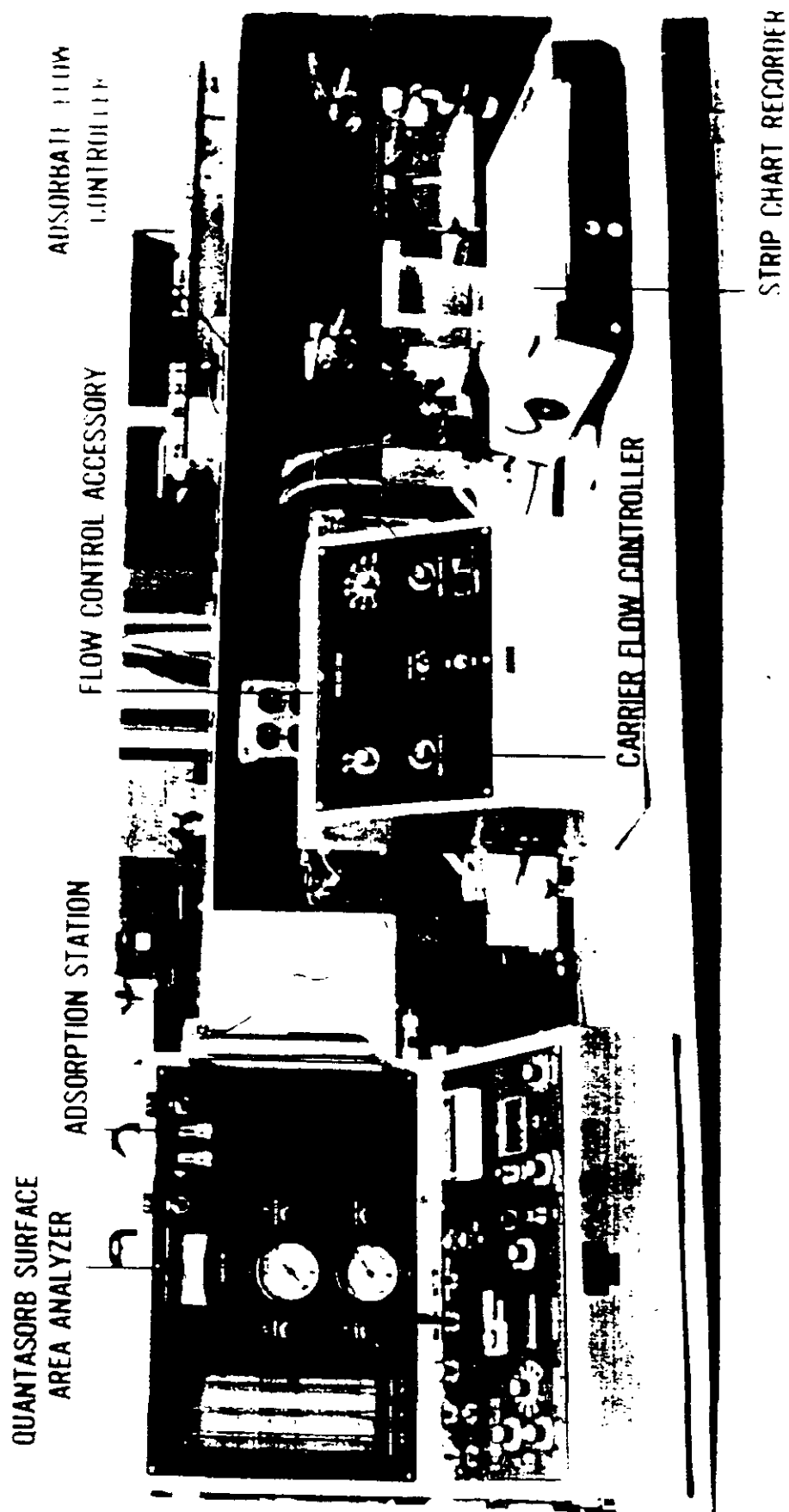


Figure A.5 Surface Area Analysis Equipment

Adsorption and desorption occur when the sample is immersed into and then withdrawn from the liquid controlling the adsorption temperature. Liquid nitrogen and room-temperature (25 °C) water are used for nitrogen adsorption and desorption, respectively.

Room temperature (25 °C) and hot (60 °C) water are used for carbon dioxide adsorption and desorption, respectively. Changes in the ratio of helium to adsorbate in the flowing stream, due to adsorption and desorption, are sensed by a specially designed thermal conductivity detector. The signals delivered by the detector are nearly Gaussian in shape. The instantaneous signal height is proportional to the rate of adsorption or desorption and the total integrated area under the curve is proportional to the quantity of gas adsorbed. As such, the function of the Quantasorb Surface Area Analyzer is to measure the quantity of gas adsorbed at a given temperature and partial pressure.

A BET (Brunauer, Emmett and Teller, 1938) single point method is used in conjunction with N₂ adsorption at -196 °C to determine the samples' BET specific surface areas. A Dubinin-Kaganer method (Gregg and Sing, 1969) is used in conjunction with CO₂ adsorption at 25 °C to determine the samples' CO₂ specific surface area.

UNDEERC BENCH-SCALE FACILITIES

Drop Tube Furnace (DTF)

UNDEERC's DTF is a laboratory-scale, entrained flow, vertical down-fired tube furnace with the ability to combust coal and produce ash under closely controlled conditions. Combustion parameters such as initial hot zone temperature, residence time, and gas cooling rates can be closely controlled and monitored.

The furnace system is housed in a laboratory that provides a clean environment for operation of the system. The furnaces are mounted on a common furnace bar and can be reconfigured to accommodate specific applications. The furnace system is designed for gas flow rates of 5 standard liters per minute. Oxygen and nitrogen mass flow controllers vary the oxygen concentration of the primary and secondary gas from 0-21%. Flowmeters split the gas mixture from the flow controllers between

primary and secondary air. Approximately one liter/minute of the gas mixture is used for primary air, and the remainder is introduced into the furnace as preheated secondary air. The unheated primary air (used as the sample carrier gas) entrains the coal from the sample feeder and carries it through the injector into the furnace. The secondary air is preheated before entering the furnace through the top of the reactor tube.

The furnace assembly consists of a 2-1/2" ID alumina reaction tube heated externally by a series of tube furnaces illustrated in Figure A-6. These furnaces possess a total of five independently controlled, electrically heated zones. This provides maximum flexibility and precise control over combustion conditions. An initial preheat furnace warms the gas that will be used as secondary air. A secondary preheat furnace further heats the secondary air before it enters the reaction tube. A split shell, two-zone furnace provides the heat for obtaining the desired reaction zone temperature. A bottom furnace is utilized to maintain the temperature of the collection zone located in the optical access section.

Coal and primary air are introduced into the furnace system by means of a traversing water-cooled injector (Figure A-7). This system injects ambient temperature primary air and coal into the furnace at the center of the tube. Secondary air is typically heated to 1000°C and introduced into the furnace through the top of the alumina tube and travels down through the tube around the injector. The traversing injection probe permits the residence time to be varied while allowing the ash deposition point to remain fixed. Thus the material to be combusted is introduced into the furnace with the primary air through the injector and combines with the preheated secondary air. The coal and gas travel down the furnace in a laminar flow regime and pass through an accelerator just above where the deposition probe is located. The ash not adhering to the probe is carried with the combustion gases into a water-cooled particulate collection probe.

The fly ash quenching probe shown in Figure A-8 is attached to the bottom of the drop-tube furnace to cool the fly ash before collection. This system is reliable and versatile. Ash collection devices can be added to the probe, such as a multicyclone

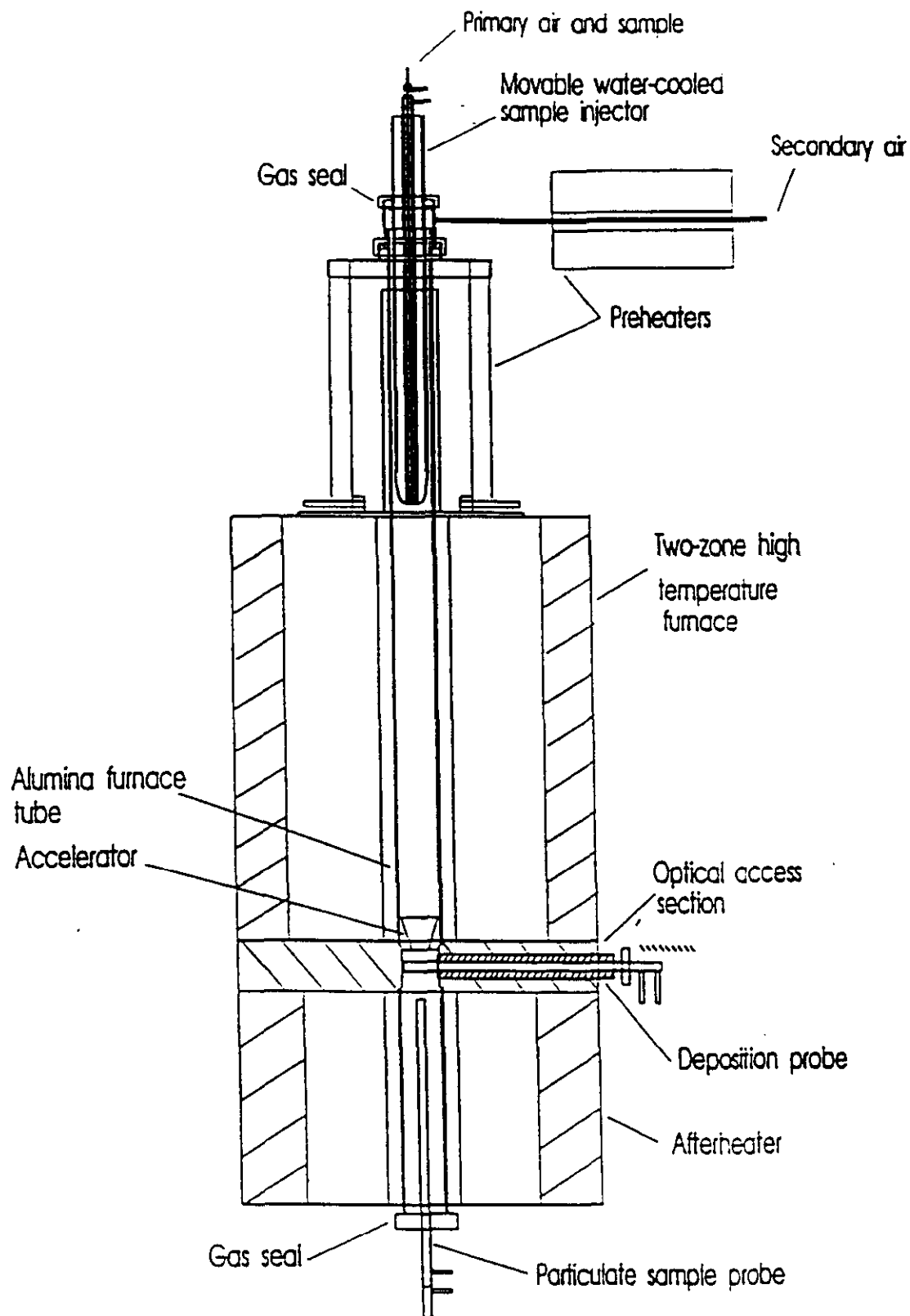


FIGURE A-6 CROSS SECTION OF UNDEERC
DROP TUBE FURNACE (DTF)

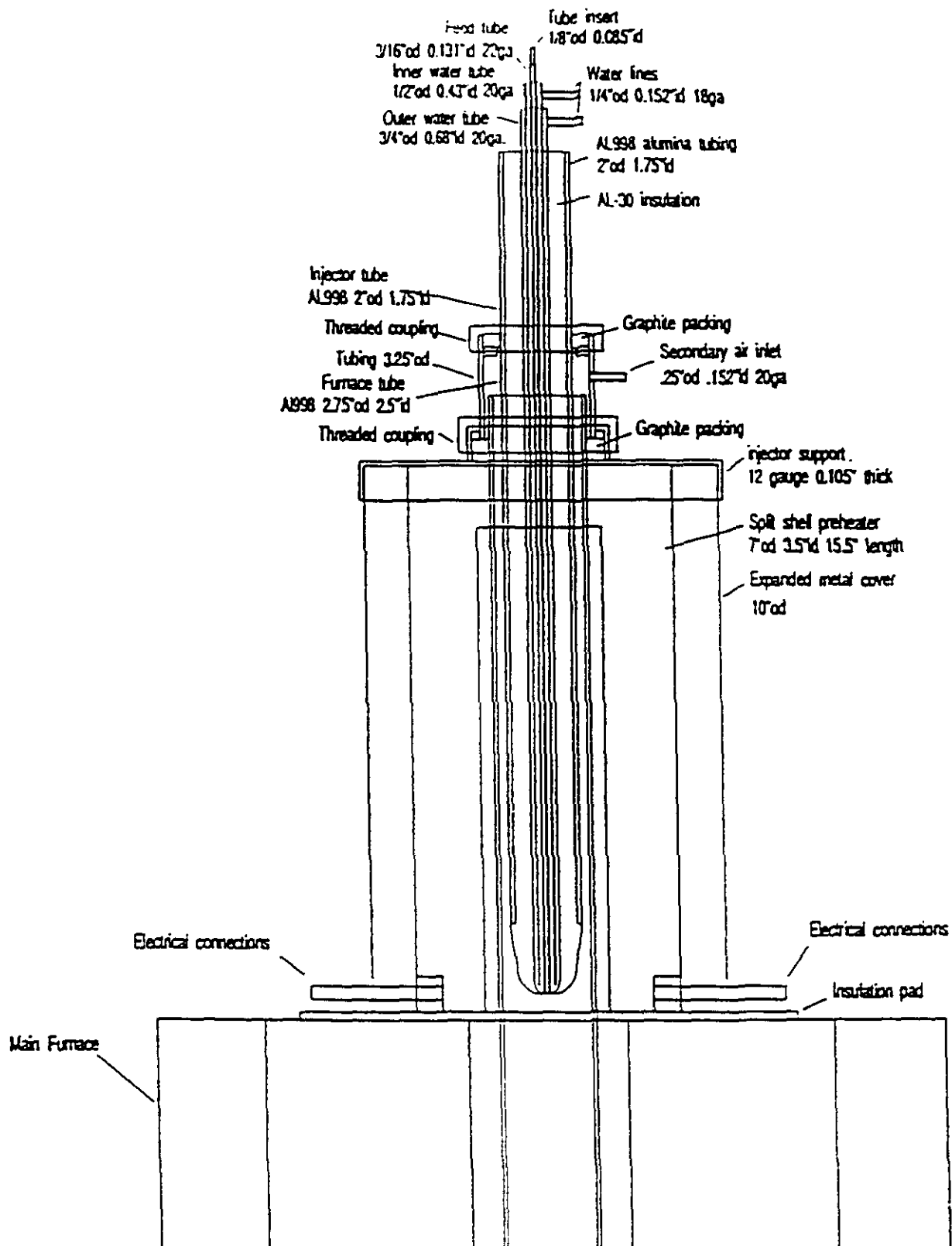


FIGURE A-7 DTF MOVABLE WATER-COOLED SAMPLE INJECTOR CONFIGURATION

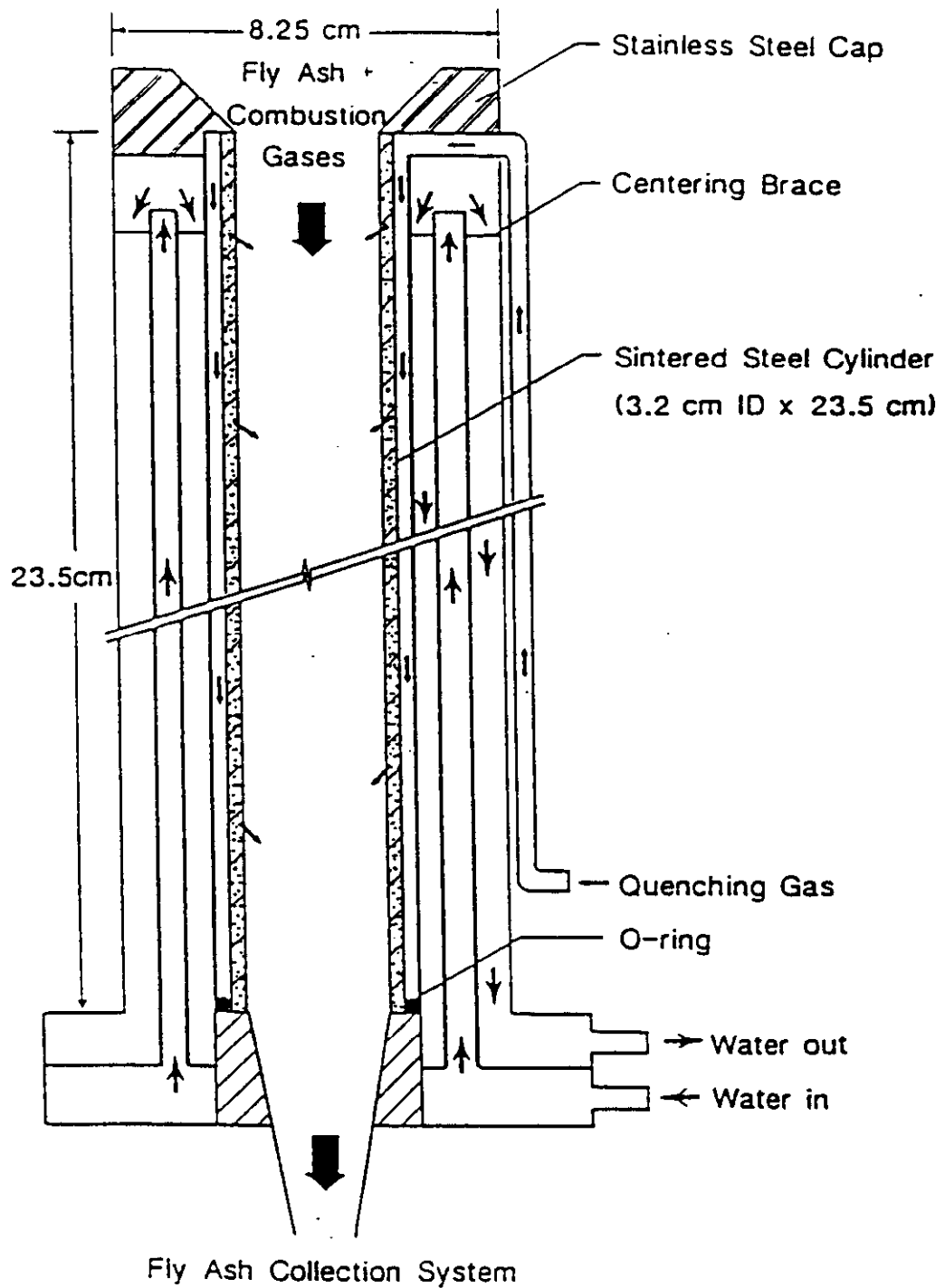


FIGURE A-8 DTF FLY ASH QUENCHING PROBE

and an impactor, to size segregate the ash. Bulk ash is collected on a Magna Nylon 66 filter placed in a 2-1/2" filter holder.

Downstream of the sampling probe and collection filter, the combustion gas is cooled and passes through a filter before entering an airtight diaphragm pump. The gas leaving the positive pressure side of the pump is passed through a flowmeter which measures the volume of gas being pulled through the probe. After the flowmeter, part of the gas is directed through carbon monoxide, carbon dioxide, and oxygen analyzers. The concentrations of these gases can then be read directly from the digital readouts of the analyzers or a chart recorder. The analyzers also send voltage signals to a computer which records the gas concentrations. The computer allows real-time comparisons of gas concentrations with coal feed rates. The configuration of this system is shown in Figure A-9.

The coal feed system is designed to feed particles of various sizes in the pulverized coal range at rates of 0.05 to 0.5 g per minute and at primary carrier gas rates of approximately one liter per minute. The basic apparatus shown in Figure A-10 consists of a pressurized cylinder in which a container filled with coal is placed. A rotating brush and stirrer attached to a variable speed motor feeds the coal from the container into a funnel where it is transported through the feed tubing into the furnace injector by the carrier gas. The coal feeder is mounted on a Sartorius top-loading balance which monitors real-time coal feed rates. The balance is connected via a RS232 to a computer which records the feed rate.

A ceramic constrictor is used to accelerate the gas flow to approximately 3-5 m/sec before it impinges on the coupon. The flow accelerator is made of Zircar AL-30 machined to fit the inside of the alumina reactor tube and coated with alumina cement. The top has a 1.27-cm hole drilled through the center and beveled at approximately 60 degrees to form the nozzle. The coupon is placed 1" (2.5 cm) below the constrictor.

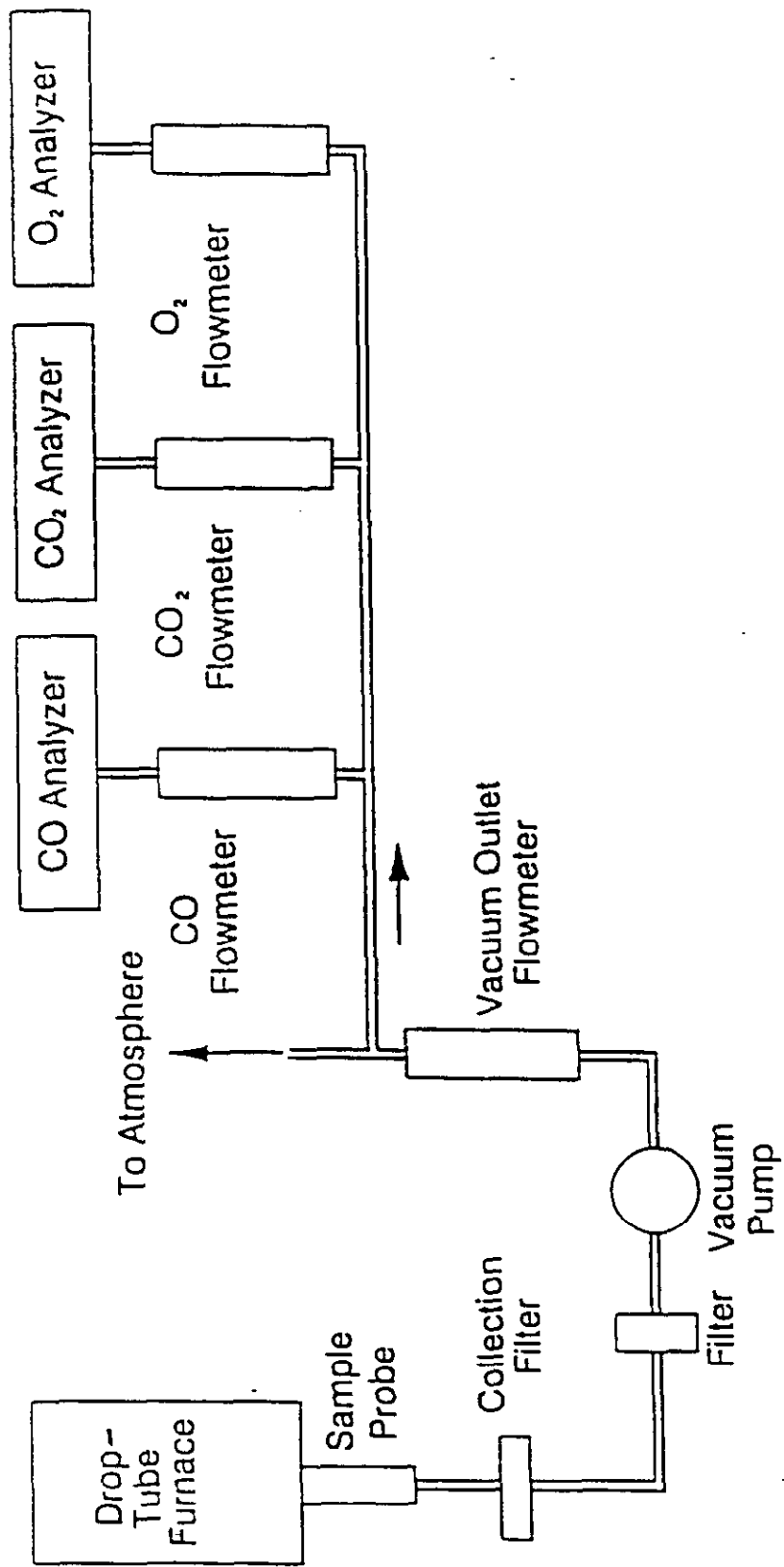


FIGURE A-9 DTF GAS SAMPLING SYSTEM

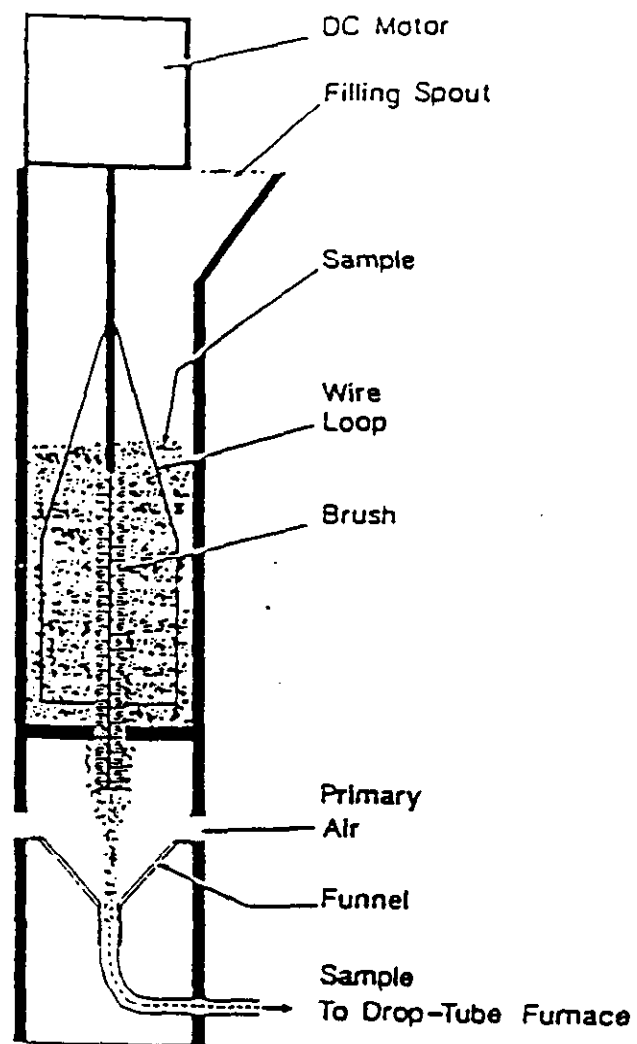


FIGURE A-10 DTF COAL FEEDER

PILOT-SCALE TEST FACILITY

CE's Fireside Performance Test Facility (FPTF) is a pilot-scale combustion facility used primarily to assess fuel properties (such as ash deposition and fly ash erosion) which influence boiler performance. It is composed of a complete fuel handling system (for both solid and liquid fuels), including a pulverizer, air preheater and an upward-fired test furnace. Schematics of these facilities are shown in Figures A-11 and A-12.

Evaluation of pulverization characteristics of solid fuels is accomplished using a CE Raymond Model 271 bowl mill. This pulverizer utilizes one spring-loaded grinding roll in a 27-inch diameter bowl driven by an external motor. The roller is positioned in the bowl so that there is no metal-to-metal contact between the roller and the bowl. When fuel is fed into the pulverizer, it is directed to the small gap between the bowl and the roller, causing the roller to turn and the material to be ground.

Crushed coal (1 in. to 1-1/2 in. top size) is fed from a large storage hopper to the pulverizer by a gravimetric belt feeder. The feeder is used to control the feed rate of the coal going into the bowl mill. The pulverizer is equipped with a direct gas-fired air heater to provide mill drying air. The coal is dried by heated air entering below the bowl. The hot air carries the pulverized coal up through the classifier and into the fuel transport piping. The particle size of the coal is controlled by adjustable vanes in the mill classifier, while the over-sized particles are returned to the mill. The outlet temperature of the pulverizer is held at a constant $140 \pm 10^{\circ}\text{F}$. The grinding roll to grinding ring distance and the spring compression can be varied as necessary to obtain the desired fuel fineness.

The pulverized coal is pneumatically transported to a cyclone collector where it is separated from the transport gases and stored in a three-ton storage hopper. The air is then passed through a bag filter which removes any remaining coal particles before venting to the atmosphere. Pulverized coal is fed by a belt-type gravimetric feeder from the hopper into a rotary air lock, from which it is pneumatically transported into the

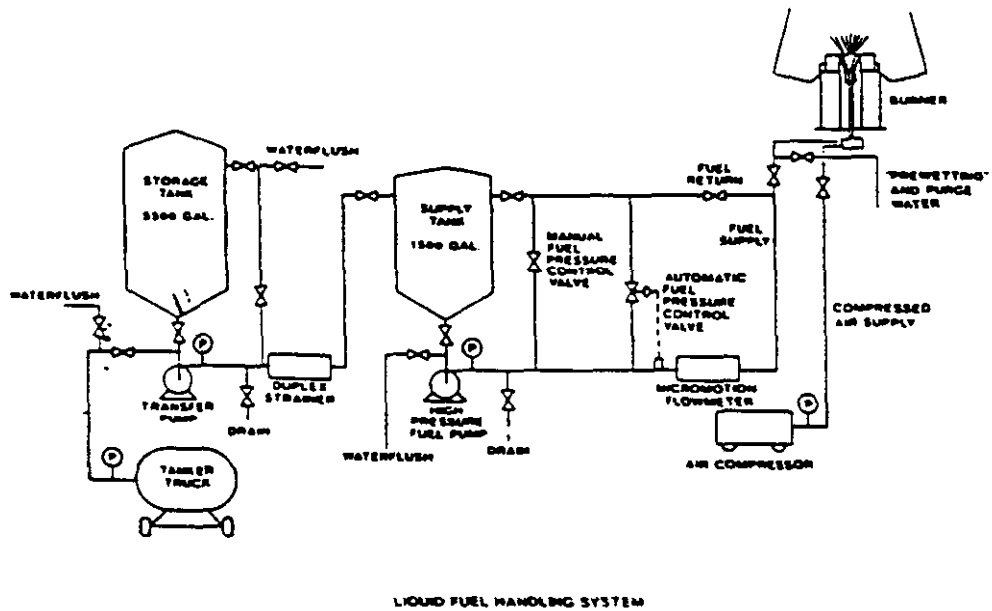
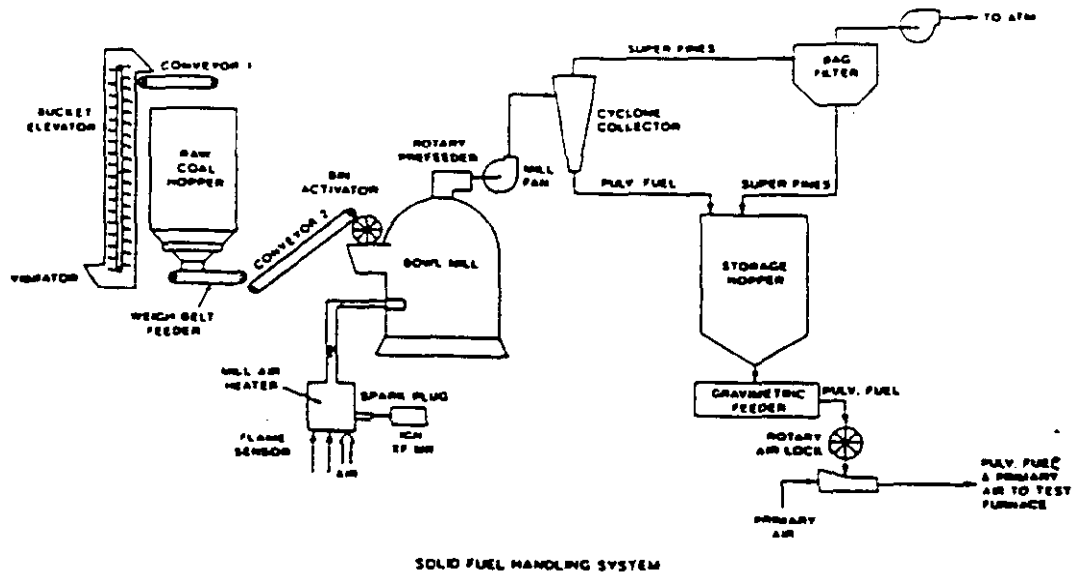


Figure A-11 Fireside Performance Test Facility Fuel Handling Systems

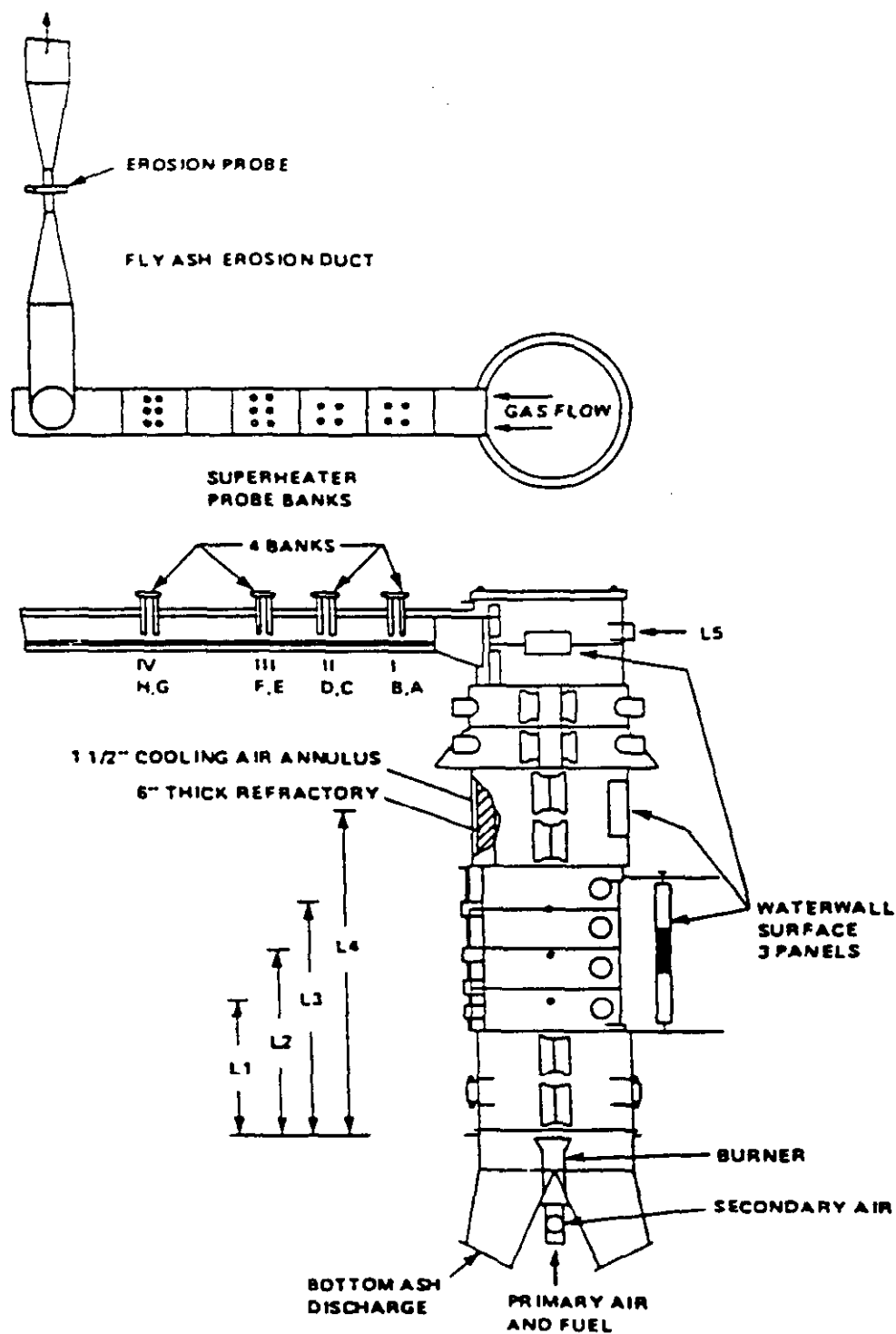


Figure A-12 Fireside Performance Test Facility (FPTF)

furnace. For pulverizer testing, the bowl mill is allowed to grind coal for fifteen minutes at the desired fuel feed rate before a test is started. A test point consists of a five-minute mill reject sample, a pulverized coal sample and a reading from the recording wattmeter for power consumption. The pulverized coal sample is then screened for size (normally percent through 200 mesh). The mill classifier vanes are adjusted as necessary to obtain the required fuel fineness.

The test furnace consists of an 18-foot high, refractory-lined 36-inch diameter cylinder. The six-inch thick refractory lining minimizes the potential heat losses associated with the large surface-to-volume ratio inherent with small furnaces. Cooling air is drawn through the 1-1/2 inch annulus surrounding the refractory lining, which provides cooling for the furnace structural shell as well as control of the heat absorption and temperature in the lower furnace.

The furnace is bottom-fired through a single swirl-type burner. Either a conventional burner for pulverized coal or a specially-designed burner for coal-water slurries can be used. The maximum firing capacity of the FPTF is approximately 5.0 MBtu/hr. Firing in this test facility is designed to simulate commercial boiler time-temperature history. The firing rate can be varied to obtain a wide range of conditions, with flame temperatures from 1900 °F to 3000 °F, and residence times from 1.0 to 2.5 seconds.

Located in the radiant section of the furnace (starting approximately three feet above the burner) are waterwall test panels, as shown in Figure A-12. These panels are used to study lower furnace ash deposition and to provide a detailed assessment of the slagging and heat transfer characteristics of the test fuel. A water-cooled frame surrounds the panels to reduce interference from molten slag generated on the hot refractory surfaces. The test panels have a total surface of approximately 4.7 square feet, and are used to model the waterwall surfaces in the lower furnace of commercial boilers. The metal temperature of the panel is typically controlled at 700 °F. Syltherm, a high boiling point organic liquid, is used as the coolant and flows through the serpentine tubing of the panels. The heat absorption rate of the panel is continuously

recorded by measuring the coolant flow rates and inlet and outlet temperatures.

Flue gas exits the lower furnace at a right angle through a horizontal water-cooled superheater duct, as shown in Figure A-12. This test section consists of five sub-sections of duct, each containing two rows of probes. This section of the FPTF can be configured to simulate the convection sections of a commercial unit. Air-cooled probes are used to simulate boiler superheater tubes. Probe metal temperatures are typically controlled at 1100 °F. Gas temperatures and velocities through these probe banks range from 1600 to 2300 °F and 30 to 70 ft/sec.

A high-velocity section is located downstream of the convection superheater duct and is used for fly ash erosion characterization. A specially-prepared test probe made of removable coupons is installed in this section. Probe metal temperatures are controlled at 800 °F. A surface activation technique is used to determine metal loss from the test probe after exposure to ash-laden flue gas. This method measures the change in the intensity of emitted radiation to determine the depth of metal erosion. The test probe is made slightly radioactive by impinging a particle beam onto its surface. As the metal surface is eroded, the level of emitted gamma radiation decreases. At the end of each test, the tube is removed and the level of emitted radiation is measured and compared to pre-test levels. Changes in radioactivity are related to the amount of metal loss due to fly ash erosion. Tube erosion from each test coal can then be accurately compared to determine the relative metal wear.

The FPTF is fully instrumented and uses a computer-controlled data acquisition system to accurately monitor and record all fuel and air inputs. Cooling flows and temperatures are measured to obtain mass and energy balances around the furnace. A gas analysis system allows for periodic on-line measurement of O₂, CO₂, CO, NO_x and SO₂ concentrations in the flue gas. The flue gas sample is obtained downstream of the FPTF convective pass probes, and is conditioned to remove fly ash and water vapor before being introduced into the individual gas analyzers.

STANDARD OPERATING PROCEDURE FOR COAL/ASH MINERAL ANALYSIS BY COMPUTER-CONTROLLED SCANNING ELECTRON MICROSCOPY

INTRODUCTION

This appendix describes a procedure employed at the Energy and Environmental Research Center (EERC) for sizing, identifying, and quantifying mineral constituents in coal and coal combustion products (fly ash and bottom ash) using a computer-controlled scanning electron microscopy (CCSEM) technique (Lee and Kelly, 1980; Huggins et al., 1980, 1982). Quantitative coal/ash mineral analysis and mineral size analysis is useful in characterizing the physical and chemical properties of coal, predicting the inorganic transformations that occur during combustion, understanding the deposition, slagging, and fouling characteristics of combusted materials, and determining the potential utilization or disposal of ash by-products. The reader is referred to Zygarlicke and Steadman (1990), Zygarlicke and others (1990), and Jones and others (1992) for additional information and examples of specific CCSEM applications.

SUMMARY OF PROCEDURE

Coals and coal combustion products to be analyzed are mounted in epoxy resin or caruba wax, cross sectioned, and polished according to ASTM Standard Practice D2797 (ASTM, 1991), or ultrasonically dispersed and mounted on filter paper. The sample is sputter coated with carbon to minimize electron-beam charging artifacts. A JEOL JSM-35 analytical SEM equipped with a Noran (formally Tracor Northern, TN) Micro-Z ultrathin window x-ray detector, TN-5500 x-ray analyzer, TN-5600 stage automation system, TN-8502 image analyzer, and a GW Electronics annular solid-state back-scattered electron (BSE) detector, is used for coal/ash mineral analysis. The automated analytical SEM, operating at a beam voltage of 15 kV and current of 0.6 nA in the BSE imaging mode, is programmed to scan preselected areas of the sample.

A modified version of Noran's Particle Recognition and Characterization (PRC) program is used to locate, size, and chemically analyze coal/ash mineral particles. Mineral particles are automatically detected by an increase in the BSE signal above a preset video threshold. The electron microbeam performs an iterative bisection of

chords to locate the detected particle's center. Eight diameters are measured to determine the particle's minimum, maximum, and average diameter. The particle's area, perimeter, and shape factor are also calculated. After the size analysis, an energy-dispersive x-ray spectrum (0-10keV) is acquired from the particle's center for a period of five seconds. Spectral regions-of-interest (ROI) are defined and the characteristic x-ray emission intensities of 12 common, mineral-forming, major and minor elements (Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti, Fe, and Ba) are measured. Relative intensities are calculated by dividing the net counts for each element by the total ROI counts for all elements. X-ray intensity data and location, size, and shape parameters for approximately 2000 particles are collected at two magnifications: 50X for 10 to 100 micron and 240X for 1 to 10 micron diameter particles. These data are transferred on-line to a personal computer where they are tabulated and stored to disk for subsequent manipulation, report generation, and archiving. The modified PRC program also has the capability to acquire and store BSE images for additional analysis.

A fortran program called PARTCHAR classifies the PRC analyses based on elemental relative intensities, relative-intensity ratios, and stoichiometric criteria into one of 33 mineral/chemical and mineral association categories (Table 1). Analyses that do not conform to any of the specified criteria are termed unclassified. The CCSEM analysis cannot distinguish polymorphous minerals (e.g., quartz versus cristobalite) or crystalline from amorphous phases because it identifies solely by chemical composition. Therefore, qualitative crystalline phase analysis data are obtained by x-ray powder diffraction and referred to for confirmation of CCSEM phase identifications whenever possible. The program allocates the classified particles according to average diameter into six intervals (1.0-2.2 μm , 2.2-4.6 μm , 4.6-10 μm , 10-22 μm , 22-46 μm , 46-100 μm) so that the size distribution of mineral/chemical types can be determined. The particle-diameter intervals are a geometric progression based on the cube root of ten. A geometric size distribution is used to lessen sectioning effects that cause the measured cross-sectional diameters of the particles to be less than or equal to the maximum diameter of the particles (Hurley, 1990). A report is generated that summarizes the results in a series of tables containing information on the number and proportions of minerals in their respective size intervals. Mineral weight percentages are calculated assuming that particle areas are proportional to volumes (DeHoff and Rhines, 1968) and mineral densities are constants (Table 1). The CCSEM analysis generates two PRC raw data files, a PARTCHAR data output file, and a summary report output file that are achieved on tape via a computer network system.

Summary Page

1. Percent Epoxy Used Average area percent of epoxy or carnauba wax mounting medium for an analyzed coal sample. Value is estimated by creating binary images of representative areas on the sample and performing an area mode histogram analysis of each image. An average value is calculated.

2. Total Mineral Area Analyzed at High Mag. - Summation of the cross-sectional areas (μm^2) measured at 240x for the 1 to 10 μm diameter particles.

3. Normalized Area Analyzed at High Mag. The total mineral area analyzed at 240x is normalized by multiplying by $(F^1N^1)/(F^2N^2)$ where F^1 and F^2 are the field sizes (μm^2) at 50x and 240x, respectively; and N^1 and N^2 are the number of frames collected on the sample at 50x and 240x, respectively. The actual sample area scanned by the electron microbeam at high magnification (240x) for the 1 to 10 μm size particles is smaller than the sample area scanned at low magnification (50x) for the 10 to 100 μm size particles. Therefore, the total mineral area analyzed at 240x is normalized so that the 1 to 10 μm size particles have equal statistical representation.

4. Total Mineral Area Analyzed at Low Mag. Summation of the cross-sectional areas (μm^2) measured at 50x for the 10 to 100 μm diameter particles.

5. Field Size Used at High Mag. and Low Mag. Total area imaged (μm^2) per frame on the sample at 240x and 50x, respectively.

6. Number of Frames at High Mag. and Low Mag. Total number of frames collected on the sample at 240x and 50x, respectively.

7. total Mineral Area on a Coal Basis - The total mineral area analyzed is expressed on a coal basis, M_t^c , by

$$M_t^c = \left(\frac{M}{C} \right) 100$$

where M is the total mineral area analyzed (M = normalized area analyzed at high mag. + total mineral area analyzed at low mag.) and C is the total coal area imaged (μm^2). C is determined from

$$C = \frac{A(100 - E)}{100}$$

where A is the total area (μm^2) imaged on the sample ($A = F^1N^1$), and E is the estimated area percent of mounting medium (percent epoxy used value).

8. Total Mineral Weight Percent on a Coal Basis. The total mineral content by weight on a coal basis, W_i^c , is calculated from

$$W_i^c = \left(\frac{\sum_{j=1}^{NP} A_j d_j^i}{d_c(C - M) + \sum_{j=1}^{NP} A_j d_j^i} \right) 100$$

where A_j is the area for particle j, d_{ji} is the density of mineral/chemical classification category i (Table 1) assigned to particle j, NP is the total number of particles analyzed, C is the total coal area imaged, M is the total mineral area analyzed, and d_c is the density of coal ($d_c = 1.4 \text{ g/cm}^3$).

9. Total Number of Points Analyzed Total number of mineral/ash particles detected and analyzed.

10. Number of Points Under Threshold Number of particle analyses excluded from the PARTCHAR mineral classification routine because of an insufficient x-ray signal for chemical characterization. Particles that emit < 600 total x-ray counts are excluded.

11. Weight Percent on a Mineral Basis The weight proportions of each mineral/chemical classification category i on a mineral basis, W_i^m are calculated from

$$W_i^m = \left(\frac{(A_i d_i)}{\sum_{j=1}^{NP} A_j d_j^i} \right) 100$$

where A_i is the total area of the particles assigned to mineral/chemical classification category i, d^i is the density (g/cm^3) for mineral/chemical classification category i

(Table 1), A_j is the area of particle j , d_{ji} is the density of mineral/chemical classification category i assigned to particle j , and NP is the total number of particles analyzed. This table of mineral weight percentages is also presented on page 4. The average diameter interval values in this and subsequent tables are in microns.

12. Area in Each Size Range Summation of the measured cross-sectional areas (μm^2) for each mineral/chemical and mineral association category in each diameter interval. The values for the 1 to 10 μm diameter particles are not normalized.

13. Normalized Area in Each Size Range Essentially the same data as in #12, except that the cross-sectional areas for the 1 to 10 μm diameter particles have been normalized.

14. Area Percent Mineral Basis The total area of the particles assigned to each mineral/chemical classification category, A_i , (#13) is converted to area percent by

$$\left(\frac{A_i}{M} \right) 100$$

where M is the total mineral area analyzed.

15. Weight Percent Mineral Basis Refer to summary page, item 11 for an explanation

16. Mineral Area Percent Coal Basis The area percent on a mineral basis values from page 3 are converted to a coal basis by multiplying by (M / C) where M is the total mineral area analyzed and C is the total coal area imaged. These values are equivalent to volume percent assuming that a representative planar section of the coal was analyzed.

17. Weight Percent Coal Basis The weight percent of each mineral/chemical classification category i on a coal basis, W_i^c , is determined by

$$W_i^c = \left(\frac{A_i d_i}{d_c (C - M) + \sum_{j=1}^{NP} A_j d_j^i} \right) 100$$

where A_i is the total area of the particles assigned to mineral/chemical classification category i , d_i is the density (g/cm^3) of mineral/chemical classification category i , A_j is the area of particle j , d_{ji} is the density of mineral/chemical category i assigned to particle j , NP is the total number of particles analyzed, C is the total coal area imaged, M is the total mineral area analyzed, and d_c is the density of coal ($d_c = 1.4 \text{ g/cm}^3$).

18. Distribution by Percent of Each Mineral Phase The distribution percent, D_i , of mineral/chemical phase i is determined by

$$D_i = \left(\frac{W'_i}{W_i} \right) 100$$

where W'_i is the weight percent of mineral/chemical classification category i in the average particle diameter interval s , and W_i is the total weight percent of mineral/chemical classification category i .

19. Number of Particles in Each Size Range Actual number of particles detected and analyzed in their respective diameter intervals.

20. Distribution of Mineral Phases (Frequency Percent) The total number of particles analyzed for each mineral/chemical classification category (#19) are converted to frequency percent by dividing by the total number of points analyzed and multiplying by 100.

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APPENDIX C

DETAILED CCSEM AND

CHEMICAL FRACTIONATION RESULTS

SUMMARY OF CCSEM RESULTS: PROG VERSION 2BF 8/21/90

SAMPLE DESCRIPTION ---> 53193164.ZAF CCTI-WAT:ISL CRK CLEAN COAL (RAW)
 SUBMITTER ---> ZYGARLICHE
 ICC # AND FUND # ---> 53193164
 RUN DATE AND TIME ---> 11 17 1991 11:34

SUMMARY OF PARAMETERS

PERCENT EPOXY USED = 57.1
 TOTAL MINERAL AREA ANALYZED AT HIGH MAG = 5332.0
 NORMALIZED AREA ANALYZED AT HIGH MAG = 537336.8
 TOTAL MINERAL AREA ANALYZED AT LOW MAG = 258023.0
 FIELD SIZE USED AT HIGH MAG = 115519.773
 FIELD SIZE USED AT LOW MAG = 2494610.477
 NUMBER OF FRAMES AT HIGH MAG = 9
 NUMBER OF FRAMES AT LOW MAG = 42
 TOTAL MINERAL AREA ON A COAL BASIS = 1.770
 TOTAL MINERAL WGHT % ON A COAL BASIS = 3.917
 TOTAL NUMBER OF POINTS ANALYZED = 1886
 NUMBER OF POINTS UNDER THRESHOLD = 10

WEIGHT PERCENT ON A MINERAL BASIS

	1.0 TO 2.2	2.2 TO 4.6	4.6 TO 10.0	10.0 TO 22.0	22.0 TO 46.0	46.0 TO 100.0	TOTALS
QUARTZ	2.0	3.8	4.3	1.5	1.1	.8	13.5
IRON OXIDE	.0	.1	1.5	.1	.0	.0	1.7
PERICLASE	.0	.0	.0	.0	.0	.0	.0
RUTILE	.0	.0	.0	.0	.0	.0	.0
ALUMINA	.0	.3	.0	.0	.0	.0	.3
CALCITE	.0	.0	.0	.0	.1	.0	.1
DOLOMITE	.0	.0	.0	.0	.0	.0	.0
ANKERITE	.0	.0	.0	.0	.0	.0	.0
KAOLINITE	1.9	5.1	4.3	1.9	1.1	.5	14.8
MONTMORILLONITE	.5	.7	.0	.2	.3	.0	1.7
K AL-SILICATE	2.7	4.1	2.6	.6	.5	.2	10.7
FE AL-SILICATE	.0	.1	.0	.0	.0	.0	.1
CA AL-SILICATE	.0	.1	.0	.0	.0	.0	.2
NA AL-SILICATE	.0	.0	.3	.1	.1	.0	.5
ALUMINOSILICATE	.1	.1	.3	.2	.2	.0	.9
MIXED AL-SILICA	.0	.0	.0	.0	.0	.0	.0
FE SILICATE	.0	.0	.0	.0	.0	.0	.0
CA SILICATE	.0	.0	.0	.0	.0	.0	.0
CA ALUMINATE	.0	.0	.0	.0	.0	.0	.0
PYRITE	5.3	6.1	8.4	6.8	4.6	1.3	32.5
PYRRHOTITE	.5	.0	.0	.0	.0	.0	.5
OXIDIZED PYRRHO	.1	.2	.0	.0	.2	.0	.5
GYPSUM	.2	.2	.0	.6	2.1	2.7	5.8
BARITE	.0	.0	.0	.0	.0	.0	.0
APATITE	.0	.0	.0	.0	.0	.0	.0
CA AL-P	.0	.0	.0	.0	.0	.0	.0
KCL	.0	.0	.0	.0	.0	.0	.0
GYPSUM/BARITE	.0	.0	.0	.0	.0	.0	.0
GYPSUM/AL-SILIC	.0	.1	.0	.0	.0	.0	.1
SI-RICH	.3	.2	.0	.3	.1	.9	1.8
CA-RICH	.0	.0	.0	.0	.0	.0	.0
CA-SI RICH	.0	.0	.0	.0	.2	.0	.2
UNKNOWN	5.8	3.6	.9	1.2	.7	1.7	14.0
TOTALS	19.6	24.9	22.5	13.7	11.1	8.1	100.0

Chemical Fractionation Results (%'s)
 ICC # 24983164 CCTI-Watson: Island Cr. Clean Coal (Raw)

	Initial (ppm)	As Oxides	Removed by H2O	Removed by NH4OAC	Removed by HCl	Remaining
Silicon	11070	23678.24	0	0	0	100
Aluminum	5798	10956.38	1	7	11	81
Iron	8643	12358.38	25	0	35	40
Titanium	336	560.80	2	0	0	98
Phosphorus	73	166.20	0	6	48	46
Calcium	1236	1729.13	56	7	10	27
Magnesium	395	654.27	16	21	0	63
Sodium	455	612.73	13	34	17	36
Potassium	983	1183.91	2	9	2	87

SUMMARY OF CCSEM RESULTS: PROG VERSION 2BF 8/21/90

SAMPLE DESCRIPTION ---> 3165.zaf CCT1 Watson Jader Coal Composite PC FPTF BeltFeed
 SUBMITTER ---> CZ
 ICC # AND FUND # ---> 53193165
 RUN DATE AND TIME ---> 11 14 1991 14:55

SUMMARY OF PARAMETERS

PERCENT EPOXY USED = 54.7
 TOTAL MINERAL AREA ANALYZED AT HIGH MAG = 5673.3
 NORMALIZED AREA ANALYZED AT HIGH MAG = 704455.9
 TOTAL MINERAL AREA ANALYZED AT LOW MAG = 213646.0
 FIELD SIZE USED AT HIGH MAG = 115519.773
 FIELD SIZE USED AT LOW MAG = 2494610.477
 NUMBER OF FRAMES AT HIGH MAG = 4
 NUMBER OF FRAMES AT LOW MAG = 23
 TOTAL MINERAL AREA ON A COAL BASIS = 3.529
 TOTAL MINERAL WGHT % ON A COAL BASIS = 8.075
 TOTAL NUMBER OF POINTS ANALYZED = 1984
 NUMBER OF POINTS UNDER THRESHOLD = 6

WEIGHT PERCENT ON A MINERAL BASIS

	1.0 TO 2.2	2.2 TO 4.6	4.6 TO 10.0	10.0 TO 22.0	22.0 TO 46.0	46.0 TO 100.0	TOTALS
QUARTZ	2.3	3.8	3.9	1.4	.4	.3	12.1
IRON OXIDE	.0	.0	.0	.1	.0	.0	.1
PERICLASE	.0	.0	.0	.0	.0	.0	.0
RUTILE	.1	.2	.0	.0	.0	.0	.3
ALUMINA	.0	.0	.0	.0	.0	.0	.0
CALCITE	.1	.0	.0	.0	.0	.0	.1
DOLOMITE	.0	.0	.0	.1	.0	.0	.1
ANKERITE	.0	.0	.0	.0	.0	.0	.0
KAOLINITE	2.8	4.6	3.6	1.5	.6	.3	13.3
MONTMORILLONITE	.7	.6	.2	.2	.2	.0	1.8
K AL-SILICATE	3.6	3.6	1.1	.9	.6	.2	9.9
FE AL-SILICATE	.0	.0	.0	.0	.0	.0	.0
CA AL-SILICATE	.0	.1	.0	.0	.0	.0	.1
NA AL-SILICATE	.0	.0	.0	.0	.0	.0	.0
ALUMINOSILICATE	.2	.3	.6	.2	.1	.0	1.4
MIXED AL-SILICA	.0	.0	.0	.0	.0	.2	.2
FE SILICATE	.0	.0	.0	.0	.0	.0	.0
CA SILICATE	.0	.0	.0	.0	.0	.0	.0
CA ALUMINATE	.0	.0	.0	.0	.0	.0	.0
PYRITE	3.5	7.0	16.7	8.6	5.6	2.8	44.2
PYRRHOTITE	.1	.2	.0	.0	.0	.0	.3
OXIDIZED PYRRHO	.1	.3	.0	.2	.0	.0	.6
GYP SUM	.2	.4	.4	.5	.3	.2	2.0
BARITE	.0	.0	.0	.0	.0	.0	.0
APATITE	.0	.0	.0	.0	.0	.0	.0
CA AL-P	.0	.0	.0	.0	.0	.0	.0
KCL	.0	.0	.0	.0	.0	.0	.0
GYP SUM/BARITE	.0	.0	.0	.0	.0	.0	.0
GYP SUM/AL-SILIC	.2	.0	.0	.0	.0	.0	.2
SI-RICH	.4	.6	.6	.2	.1	.0	1.8
CA-RICH	.1	.0	.0	.0	.0	.0	.1
CA-SI RICH	.0	.0	.0	.0	.0	.0	.0
UNKNOWN	5.9	4.1	.8	.7	.2	.0	11.7
TOTALS	20.0	25.8	27.8	14.5	8.1	3.8	100.0

Chemical Fractionation Results (%'s)
 Jader Coal Composite PC FPTF Belt Feed
 ICC # 24983165

	Initial (ppm)	As Oxides	Removed by H2O	Removed by NH4OAC	Removed by HCl	Remaining
Silicon	19869	42500.30	0	0	0	100
Aluminum	9417	17794.84	2	0	7	91
Iron	13835	19781.64	33	0	33	34
Titanium	352	587.40	0	0	0	100
Phosphorus	98	224.65	27	14	13	46
Calcium	1654	2315.06	61	3	7	30
Magnesium	709	1174.81	39	3	12	46
Sodium	192	259.15	22	15	7	56
Potassium	1463	1762.21	6	2	8	84

ENERGY & ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
X-RAY POWDER DIFFRACTION REPORT

P.I.: Zygarlicke DATE: 9-5-91 ICC#: 53193169.XRD

SAMPLE DESCRIPTION: CCTI-Watson: Jader Coal Baseline Test 4
Water Wall Panel 1 Inner

MAJOR PHASE(S):

NOMINAL COMPOSITION(S):

Hematite

Fe_2O_3

Quartz

SiO_2

Mullite

$\text{Al}_6\text{Si}_4\text{O}_{13}$

MINOR PHASE(S):

NOMINAL COMPOSITION(S):

Ferrite Spinel

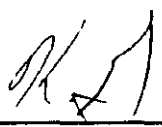
$(\text{Mg}, \text{Fe}) (\text{Fe}, \text{Al})_2\text{O}_4$

Anhydrite

CaSO_4

COMMENTS:

Analyzed by



3. ANALYSIS OF THE SAMPLES - IS THE
 ANALYSIS OF THE SAMPLES
 IS THE ANALYSIS OF THE SAMPLES

Date: 9-18-81

Intergate Base Center Number: ED17116A

Coal Laboratory Number: 81-1031

Sample Description: Upper Bit. 50 T. W. Panel 1, 1000

Intergate Base Center Number: ED17116A

Analysis: 1000 Base Center

Conc.	(a)	(b)	(c)
-----	-----	-----	-----
ASH	32.3	45.3	46.1
AL2O3	12.5	17.3	18.0
SiO2	17.9	25.0	25.3
TiO2	0.63	0.83	0.90
Fe2O3	0.33	0.46	0.47
CaO	3.44	3.45	3.51
MgO	0.83	1.17	1.19
Na2O	0.30	0.42	0.43
K2O	2.31	3.25	3.32
S O2	1.29	1.22	---
Total	70.3		

(a) Concentrations (wt.%) on an ash basis.

(b) Concentrations normalized to a closure of 100%.

(c) Concentrations renormalized to a SO3-free basis.

Comments:

Large errors because of poor sample pellet.

TOTAL NUMBER OF POINTS = 250.0

SILICATE AND OTHER CRYSTALLINE PHASES

AKERMANITE	=	.0
SEHLENITE	=	.0
ANORTHITE	=	1.2
ALBITE	=	.0
NEPHELINE	=	.0
LEUCITE	=	.0
POTASSIUM FELDSPAR	=	.0
PYROXENE	=	.0
MULLITE	=	.0
MERWINITE	=	.0
CALCIUM SILICATE	=	.0
(CA,MG,FE)SIO3	=	.0
DICALCIUM SILICATE	=	.0
SPURRITE	=	.0
NA2CASIO4	=	.0
HAUYNE	=	.0
CALCIUM ALUMINATE	=	.0
SPINEL	=	.0
CALCIUM TITANATE	=	.0

OXIDE OR CARBONATE PHASES

QUARTZ	=	10.4
IRON OXIDE	=	7.2
CALCIUM OXIDE	=	.0
MAGNESIUM OXIDE	=	.0
ANKERITE (CA,MG,FE)CO3	=	.0
ALUMINUM OXIDE	=	.0
RUTILE	=	.0
DOLOMITE	=	.0

SULFATE AND SULFIDE PHASES

BARITE	=	.0
ANHYDRITE	=	.0
SULFATED DOLOMITE	=	.0
SULFATED ANKERITE	=	.0
SODIUM SULFATE	=	.0
SODIUM CALCIUM SULFATE	=	.0
FERRIC SULFATE	=	.0
PYRRHOTITE	=	.0
PYRITE	=	.0

UNCLASSIFIED AND DESIGNATED AMORPHOUS PHASES

UNCLASSIFIED	=	63.2
PURE KAOLINITE (AMORP)	=	3.2
KAOLINITE DERIVED	=	6.4
ILLITE (AMORP)	=	6.4
MONTMORILLONITE (AMORP)	=	2.0

THE FOLLOWING ARE ODD CRYSTALLINE PHASES

APATITE	=	.0
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CALCIUM DERIVED POINTS

CALCIUM DERIVED	=	.0
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CHEMICAL COMPOSITION WT %

	SIO2	AL2O3	FE2O3	TIO2	P2O5	CAO	MGO	NA2O	K2O	SO3	BAO	CR2O3	CLO
3ULK	51.8	19.7	18.8	.8	.4	2.3	1.2	.8	2.7	1.0	.0	.4	.1
AMORP.	51.5	23.6	15.1	.9	.5	2.4	1.4	.9	3.2	.0	.0	.5	.0

ENERGY & ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
X-RAY POWDER DIFFRACTION REPORT

P.I.: Zygarlicke DATE: 9-5-91 ICC#: 53193170.XRD

SAMPLE DESCRIPTION: CCTI-Watson: Jader Coal Baseline Test 4
Water Wall Panel 1 Outer

MAJOR PHASE(S):

Hematite

Mullite

NOMINAL COMPOSITION(S):

Fe_2O_3

$\text{Al}_6\text{Si}_4\text{O}_{13}$

MINOR PHASE(S):

Ferrite Spinel

Quartz

NOMINAL COMPOSITION(S):

$(\text{Mg}, \text{Fe}) (\text{Fe}, \text{Al})_2\text{O}_4$

SiO_2

COMMENTS:

Analyzed by



- total because of poor sample pellet

TOTAL NUMBER OF POINTS = 250.0

SILICATE AND OTHER CRYSTALLINE PHASES

ANKERMANITE	=	.0
JEHLNITE	=	.0
% ANORTHITE	=	.0
% ALBITE	=	.0
% NEPHELINE	=	.0
% LEUCITE	=	.0
% POTASSIUM FELDSPAR	=	.0
% PYROXENE	=	.0
% MULLITE	=	.0
% MERWINITE	=	.0
% CALCIUM SILICATE	=	.0
% (CA,MG,FE)SIO3	=	.0
% DICALCIUM SILICATE	=	.0
% SPURRITE	=	.0
% NA2CASIO4	=	.0
% HAUYNE	=	.0
% CALCIUM ALUMINATE	=	.0
% SPINEL	=	.0
% CALCIUM TITANATE	=	.0

OXIDE OR CARBONATE PHASES

% QUARTZ	=	9.2
% IRON OXIDE	=	8.0
% CALCIUM OXIDE	=	.0
% MAGNESIUM OXIDE	=	.0
% ANKERITE (CA,MG,FE)CO3	=	.0
% ALUMINUM OXIDE	=	.0
% RUTILE	=	.0
% DOLOMITE	=	.0

SULFATE AND SULFIDE PHASES

% BARITE	=	.0
% ANHYDRITE	=	.4
% SULFATED DOLOMITE	=	.0
% SULFATED ANKERITE	=	.0
% SODIUM SULFATE	=	.0
% SODIUM CALCIUM SULFATE	=	.0
% FERRIC SULFATE	=	.0
% PYRRHOTITE	=	.0
% PYRITE	=	.0

UNCLASSIFIED AND DESIGNATED AMORPHOUS PHASES

% UNCLASSIFIED	=	57.2
% PURE KAOLINITE (AMORP)	=	4.8
% KAOLINITE DERIVED	=	6.0
% ILLITE (AMORP)	=	8.0
% MONTMORILLONITE (AMORP)	=	6.4

THE FOLLOWING ARE ODD CRYSTALLINE PHASES

% APATITE	=	.0
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CALCIUM DERIVED POINTS

% CALCIUM DERIVED	=	.0
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CHEMICAL COMPOSITION WT %

	SIO2	AL2O3	FE2O3	TIO2	P2O5	CAO	MGO	NA2O	K2O	SO3	BAO	CR2O3	CLO
BULK	53.4	19.4	18.0	1.0	.5	2.5	1.1	.7	2.8	.5	.0	.1	.1
AMORP.	53.6	22.7	13.8	1.1	.6	2.8	1.3	.8	3.3	.0	.0	.1	.0

TOTAL NUMBER OF POINTS = 250.0

SILICATE AND OTHER CRYSTALLINE PHASES

% AKERMANITE	=	.0
% GEHLENITE	=	.0
% ANORTHITE	=	.0
% ALBITE	=	.0
% NEPHELINE	=	.0
% LEUCITE	=	.0
% POTASSIUM FELDSPAR	=	.0
% PYROXENE	=	.0
% MULLITE	=	.0
% MERWINITE	=	.0
% CALCIUM SILICATE	=	.0
% (CA,MG,FE)SIO3	=	.0
% DICALCIUM SILICATE	=	.0
% SPURRITE	=	.0
% NA2CASIO4	=	.0
% HAUYNE	=	.0
% CALCIUM ALUMINATE	=	.0
% SPINEL	=	.0
% CALCIUM TITANATE	=	.0

OXIDE OR CARBONATE PHASES

% QUARTZ	=	8.4
% IRON OXIDE	=	5.2
% CALCIUM OXIDE	=	.0
% MAGNESIUM OXIDE	=	.0
% ANKERITE (CA,MG,FE)CO3	=	.0
% ALUMINUM OXIDE	=	.0
% RUTILE	=	.0
% DOLOMITE	=	.0

SULFATE AND SULFIDE PHASES

% BARITE	=	.0
% ANHYDRITE	=	.0
% SULFATED DOLOMITE	=	.0
% SULFATED ANKERITE	=	.4
% SODIUM SULFATE	=	.0
% SODIUM CALCIUM SULFATE	=	.0
% FERRIC SULFATE	=	.0
% PYRRHOTITE	=	.0
% PYRITE	=	.0

UNCLASSIFIED AND DESIGNATED AMORPHOUS PHASES

% UNCLASSIFIED	=	72.8
% PURE KAOLINITE (AMORP)	=	.0
% KAOLINITE DERIVED	=	11.2
% ILLITE (AMORP)	=	2.0
% MONTMORILLONITE (AMORP)	=	.0

THE FOLLOWING ARE ODD CRYSTALLINE PHASES

% APATITE	=	.0
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CALCIUM DERIVED POINTS

% CALCIUM DERIVED	=	.0
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CHEMICAL COMPOSITION WT %

	SIO2	AL2O3	FE2O3	TIO2	P2O5	CAO	MGO	NA2O	K2O	SO3	BAO	CR2O3	CLO
BULK	46.7	19.3	19.2	.9	.2	2.3	1.0	1.0	2.4	4.9	.0	.1	1.9
AMORP.	48.4	23.7	18.1	1.1	.3	2.9	1.3	1.2	3.0	.0	.0	.1	.0

TOTAL NUMBER OF POINTS = 250.0

SILICATE AND OTHER CRYSTALLINE PHASES

% AKERMANITE = .0
 % GEHLENITE = .0
 % ANORTHITE = .0
 % ALBITE = .0
 % NEPHELINE = .0
 % LEUCITE = .0
 % POTASSIUM FELDSPAR = .0
 % PYROXENE = .0
 % MULLITE = .0
 % MERWINITE = .0
 % CALCIUM SILICATE = .0
 % (CA,MG,FE)SIO3 = .0
 % DICALCIUM SILICATE = .0
 % SPURRITE = .0
 % NA2CASIO4 = .0
 % HAUYNE = .0
 % CALCIUM ALUMINATE = .0
 % SPINEL = .0
 % CALCIUM TITANATE = .0

OXIDE OR CARBONATE PHASES

% QUARTZ = 15.2
 % IRON OXIDE = 7.2
 % CALCIUM OXIDE = .0
 % MAGNESIUM OXIDE = .0
 % ANKERITE (CA,MG,FE)CO3 = .0
 % ALUMINUM OXIDE = .0
 % RUTILE = .0
 % DOLOMITE = .0

SULFATE AND SULFIDE PHASES

% BARITE = .0
 % ANHYDRITE = .8
 % SULFATED DOLOMITE = .0
 % SULFATED ANKERITE = .0
 % SODIUM SULFATE = .0
 % SODIUM CALCIUM SULFATE = .0
 % FERRIC SULFATE = .0
 % PYRRHOTITE = .0
 % PYRITE = .0

UNCLASSIFIED AND DESIGNATED AMORPHOUS PHASES

% UNCLASSIFIED = 63.6
 % PURE KAOLINITE (AMORP) = 1.2
 % KAOLINITE DERIVED = 9.6
 % ILLITE (AMORP) = 1.6
 % MONTMORILLONITE (AMORP) = .8

THE FOLLOWING ARE ODD CRYSTALLINE PHASES

% APATITE = .0

CALCIUM DERIVED POINTS

% CALCIUM DERIVED = .0

CHEMICAL COMPOSITION WT %

	SIO2	AL2O3	FE2O3	TIO2	P2O5	CAO	MGO	NA2O	K2O	SO3	BAO	CR2O3	CLO
BULK	53.0	17.1	18.9	.7	.1	2.0	.9	.7	2.0	3.1	.0	.1	1.4
AMORP.	52.8	22.7	16.5	.9	.2	2.1	1.1	.9	2.6	.0	.0	.1	.0

ENERGY & ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
X-RAY POWDER DIFFRACTION REPORT

P.I.: Zygarlicke DATE: 9-5-91 ICC#: 53193176.XRD

SAMPLE DESCRIPTION: CCTI-Watson: Jader Coal Low XS-Air Test 4 WW
Panel 1 Inner

MAJOR PHASE(S):

Hematite

NOMINAL COMPOSITION(S):

Fe_2O_3

MINOR PHASE(S):

Quartz

Cristobalite

Anhydrite

Ferrite Spinel

Mullite

NOMINAL COMPOSITION(S):

SiO_2

SiO_2

CaSO_4

$(\text{Mg}, \text{Fe})(\text{Fe}, \text{Al})_2\text{O}_4$

$\text{Al}_6\text{Si}_4\text{O}_{13}$

COMMENTS:

Analyzed by 

ENERGY AND ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
EDXRF ANALYSIS REPORT

Date: 21-AUG-91

Inorganic Cost Center Number: E3193175

Coal Laboratory Number: 91-1396

Sample Description: Jaden Low AS Air T- WW Panel 1 Inner

Sample Submitter: Tygarlicke

Analyst: Kevin Galbreath

Oxides (wt.%)	(a)	(b)	(c)
-----	----	----	----
SiO2	39.5	41.7	44.5
Al2O3	15.9	16.8	17.9
FeO	23.8	25.1	26.8
TiO2	0.62	0.65	0.69
P2O5	0.74	0.78	0.84
CaO	2.33	2.45	2.62
MgO	1.98	2.09	2.23
Na2O	0.67	0.71	0.75
K2O	3.20	3.37	3.60
S O3	6.10	6.43	---
Total	94.8		

(a) Concentrations (wt.%) on an ash basis.

(b) Concentrations normalized to a closure of 100%.

(c) Concentrations renormalized to a SO3-free basis.

Comments:

TOTAL NUMBER OF POINTS = 250.0

SILICATE AND OTHER CRYSTALLINE PHASES

AKERMANITE	=	.0
% GEHLENITE	=	.0
% ANORTHITE	=	.0
% ALBITE	=	.0
% NEPHELINE	=	.0
% LEUCITE	=	.0
% POTASSIUM FELDSPAR	=	.0
% PYROXENE	=	.0
% MULLITE	=	.0
% MERWINITE	=	.0
% CALCIUM SILICATE	=	.0
% (CA,MG,FE)SIO3	=	.0
% DICALCIUM SILICATE	=	.0
% SPURRITE	=	.0
% NA2CASIO4	=	.0
% HAUYNE	=	.0
% CALCIUM ALUMINATE	=	.0
% SPINEL	=	.0
% CALCIUM TITANATE	=	.0

OXIDE OR CARBONATE PHASES

% QUARTZ	=	6.8
% IRON OXIDE	=	13.6
% CALCIUM OXIDE	=	.0
% MAGNESIUM OXIDE	=	.0
% ANKERITE (CA,MG,FE)CO3	=	.0
% ALUMINUM OXIDE	=	.0
% RUTILE	=	.0
% DOLOMITE	=	.0

SULFATE AND SULFIDE PHASES

% BARITE	=	.0
% ANHYDRITE	=	.0
% SULFATED DOLOMITE	=	.0
% SULFATED ANKERITE	=	.0
% SODIUM SULFATE	=	.0
% SODIUM CALCIUM SULFATE	=	.0
% FERRIC SULFATE	=	.0
% PYRRHOTITE	=	.0
% PYRITE	=	.0

UNCLASSIFIED AND DESIGNATED AMORPHOUS PHASES

% UNCLASSIFIED	=	67.2
% PURE KAOLINITE (AMORP)	=	1.6
% KAOLINITE DERIVED	=	7.2
% ILLITE (AMORP)	=	2.0
% MONTMORILLONITE (AMORP)	=	1.6

THE FOLLOWING ARE ODD CRYSTALLINE PHASES

% APATITE	=	.0
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CALCIUM DERIVED POINTS

% CALCIUM DERIVED	=	.0
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CHEMICAL COMPOSITION WT %

	SIO2	AL2O3	FE2O3	TIO2	P2O5	CAO	MGO	NA2O	K2O	SO3	BAO	CR2O3	CLO
BULK	39.9	16.3	25.5	1.3	.3	2.1	1.4	1.4	3.6	7.4	.0	.2	.5
AMORP.	45.3	21.5	19.1	1.7	.4	3.2	2.0	1.8	4.8	.0	.0	.3	.0

ENERGY & ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
X-RAY POWDER DIFFRACTION REPORT

P.I.: Zygarlicke DATE: 9-5-91 ICC#: 53193177.XRD

SAMPLE DESCRIPTION: CCTI-Watson: Jader Coal Low XS-Air Test 4 WW
Panel 4 Outer

MAJOR PHASE(S):

NOMINAL COMPOSITION(S):

Hematite

Fe_2O_3

Mullite

$\text{Al}_6\text{Si}_4\text{O}_{13}$

MINOR PHASE(S):

NOMINAL COMPOSITION(S):

Quartz

SiO_2

Cristobalite

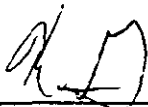
SiO_2

Ferrite Spinel

$(\text{Mg}, \text{Fe}) (\text{Fe}, \text{Al})_2\text{O}_4$

COMMENTS:

Analyzed by



ENERGY AND ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
EDXRF ANALYSIS REPORT

Date: 21-AUG-91

Inorganic Cost Center Number: 53193177

Coal Laboratory Number: 91-1397

Sample Description: Jader Low XS Air T4 WW Panel 1: Euter

Sample Submitter: Lygarlioka

Analyst: Kevin Galbreath

Oxides (wt.%) -----	(a) ----	(b) ----	(c) ----
SiO2	53.6	53.3	53.4
AL2O3	18.6	17.5	17.5
Fe2O3	27.9	26.2	26.3
TiO2	0.49	0.46	0.46
P2O5	0.07	0.07	0.07
CaO	2.29	2.15	2.15
MgO	0.93	0.87	0.88
K2O	2.06	1.93	1.94
Na2O	0.27	0.25	0.25
S O3	0.28	0.27	---
Total	106.5		

(a) Concentrations (wt.%) on an ash basis.

(b) Concentrations normalized to a closure of 100%.

(c) Concentrations renormalized to a SO3-free basis.

Comments:

TOTAL NUMBER OF POINTS = 250.0

SILICATE AND OTHER CRYSTALLINE PHASES

AKERMANITE	=	.0
% GEHLENITE	=	.4
% ANORTHITE	=	.0
% ALBITE	=	.0
% NEPHELINE	=	.0
% LEUCITE	=	.0
% POTASSIUM FELDSPAR	=	.0
% PYROXENE	=	.0
% MULLITE	=	.0
% MERWINITE	=	.0
% CALCIUM SILICATE	=	.0
% (CA,MG,FE) SiO3	=	.0
% DICALCIUM SILICATE	=	.0
% SPURRITE	=	.0
% Na2CaSiO4	=	.0
% HAUYNE	=	.0
% CALCIUM ALUMINATE	=	.0
% SPINEL	=	.0
% CALCIUM TITANATE	=	.0

OXIDE OR CARBONATE PHASES

% QUARTZ	=	9.2
% IRON OXIDE	=	12.0
% CALCIUM OXIDE	=	.0
% MAGNESIUM OXIDE	=	.0
% ANKERITE (CA,MG,FE) CO3	=	.0
% ALUMINUM OXIDE	=	.0
% RUTILE	=	.0
% DOLOMITE	=	.0

SULFATE AND SULFIDE PHASES

% BARITE	=	.0
% ANHYDRITE	=	.0
% SULFATED DOLOMITE	=	.0
% SULFATED ANKERITE	=	.0
% SODIUM SULFATE	=	.0
% SODIUM CALCIUM SULFATE	=	.0
% FERRIC SULFATE	=	.0
% PYRRHOTITE	=	.0
% PYRITE	=	.0

UNCLASSIFIED AND DESIGNATED AMORPHOUS PHASES

% UNCLASSIFIED	=	60.4
% PURE KAOLINITE (AMORP)	=	5.2
% KAOLINITE DERIVED	=	4.4
% ILLITE (AMORP)	=	7.2
% MONTMORILLONITE (AMORP)	=	1.2

THE FOLLOWING ARE ODD CRYSTALLINE PHASES

% APATITE	=	.0
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CALCIUM DERIVED POINTS

% CALCIUM DERIVED	=	.0
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CHEMICAL COMPOSITION WT %

	SiO2	Al2O3	Fe2O3	TiO2	P2O5	CaO	MgO	Na2O	K2O	3	BAO	CR2O3	CLO
BULK	53.3	19.0	19.8	.8	.1	1.7	.9	.5	2.1	1	.0	.1	.5
AMORP.	56.9	23.3	12.7	.9	.1	1.9	1.0	.6	2.6		.0	.1	.0

ENERGY & ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
X-RAY POWDER DIFFRACTION REPORT

P.I.: Zygarlicke DATE: 9-5-91 ICC#: 53193178.XRD

SAMPLE DESCRIPTION: CCTI-Watson: Jader Coal Low XS-Air Test 4
Inflame Solids SH Duct 1A Inner

MAJOR PHASE(S):

Hematite

NOMINAL COMPOSITION(S):

Fe_2O_3

MINOR PHASE(S):

Quartz

Anhydrite

Ferrite Spinel

NOMINAL COMPOSITION(S):

SiO_2

CaSO_4

$(\text{Mg}, \text{Fe}) (\text{Fe}, \text{Al})_2\text{O}_4$

COMMENTS:

Analyzed by

K.S.

ENERGY AND ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
EDXRF ANALYSIS REPORT

Date: 21-AUG-91

Inorganic Cost Center Number: 53193178

Coal Laboratory Number: 91-1398

Sample Description: Jaden Low XS Air T4 IFB SH Duct 1A Inner

Sample Submitter: Tygarhoke

Analyst: Kevin Galbreath

Oxides (wt.%)	(a)	(b)	(c)
-----	----	----	----
SiO2	29.7	30.8	31.7
Al2O3	11.6	12.0	12.3
SO3	46.2	46.0	49.3
TiO2	0.45	0.46	0.47
P2O5	0.00	0.00	0.00
CaO	3.32	3.45	3.54
MgO	1.31	1.36	1.40
Na2O	0.20	0.21	0.21
K2O	0.99	1.03	1.06
S O3	2.58	2.68	---
Total	96.3		

(a) Concentrations (wt.%) on an ash basis.

(b) Concentrations normalized to a closure of 100%.

(c) Concentrations renormalized to a SO3-free basis.

Comments:

TOTAL NUMBER OF POINTS = 250.0

SILICATE AND OTHER CRYSTALLINE PHASES

AKERMANITE	=	.0
% GEHLENITE	=	.0
% ANORTHITE	=	.0
% ALBITE	=	.0
% NEPHELINE	=	.0
% LEUCITE	=	.0
% POTASSIUM FELDSPAR	=	.0
% PYROXENE	=	.0
% MULLITE	=	.0
% MERWINITE	=	.0
% CALCIUM SILICATE	=	.0
% (CA,MG,FE)SIO3	=	.0
% DICALCIUM SILICATE	=	.0
% SPURRITE	=	.0
% NA2CASIO4	=	.0
% HAUYNE	=	.0
% CALCIUM ALUMINATE	=	.0
% SPINEL	=	.0
% CALCIUM TITANATE	=	.0

OXIDE OR CARBONATE PHASES

% QUARTZ	=	6.4
% IRON OXIDE	=	38.0
% CALCIUM OXIDE	=	.0
% MAGNESIUM OXIDE	=	.0
% ANKERITE (CA,MG,FE)CO3	=	.4
% ALUMINUM OXIDE	=	.0
% RUTILE	=	.0
% DOLOMITE	=	.0

SULFATE AND SULFIDE PHASES

% BARITE	=	.0
% ANHYDRITE	=	1.6
% SULFATED DOLOMITE	=	.4
% SULFATED ANKERITE	=	.4
% SODIUM SULFATE	=	.0
% SODIUM CALCIUM SULFATE	=	.0
% FERRIC SULFATE	=	.0
% PYRRHOTITE	=	.0
% PYRITE	=	.0

UNCLASSIFIED AND DESIGNATED AMORPHOUS PHASES

% UNCLASSIFIED	=	47.2
% PURE KAOLINITE (AMORP)	=	.4
% KAOLINITE DERIVED	=	4.4
% ILLITE (AMORP)	=	.8
% MONTMORILLONITE (AMORP)	=	.0

THE FOLLOWING ARE ODD CRYSTALLINE PHASES

% APATITE	=	.0
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CALCIUM DERIVED POINTS

% CALCIUM DERIVED	=	.0
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CHEMICAL COMPOSITION WT %

	SIO2	AL2O3	FE2O3	TIO2	P2O5	CAO	MGO	NA2O	K2O	SO3	BAO	CR2O3	CLO
BULK	29.3	10.6	47.4	.5	.3	4.3	1.0	.6	.9	4.7	.0	.1	.2
AMORP.	42.7	19.0	25.8	.9	.8	6.9	1.4	.6	1.7	.0	.0	.1	.0

ENERGY & ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
X-RAY POWDER DIFFRACTION REPORT

P.I.: Zygarlicke DATE: 9-5-91 ICC#: 53193179.XRD

SAMPLE DESCRIPTION: CCTI-Watson: Jader Coal Low XS-Air Test 4
Inflame Solids SH Duct 1A Outer

MAJOR PHASE(S):

NOMINAL COMPOSITION(S):

Hematite

Fe_2O_3

Mullite

$\text{Al}_6\text{Si}_4\text{O}_{13}$

Quartz

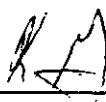
SiO_2

MINOR PHASE(S):

NOMINAL COMPOSITION(S):

COMMENTS:

Analyzed by



ENERGY AND ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
EDXRF ANALYSIS REPORT

Date: 21-AUG-91

Inorganic Cost Center Number: 53193179

Coal Laboratory Number: 91-1369

Sample Description: Jaden Low XS Run T4 IFB SH Duct 1A Outer

Sample Submitted: Dygenhoke

Analyst: Kevin Salomeath

Oxides (wt.%)	(a)	(b)	(c)
-----	----	----	----
SiO2	55.5	52.3	52.3
Al2O3	20.8	19.6	19.6
SO3	23.4	22.1	22.1
TiO2	0.67	0.63	0.63
P2O5	0.07	0.07	0.07
CaO	2.45	2.30	2.30
MgO	0.93	0.88	0.88
K2O	1.98	1.86	1.86
Na2O	0.23	0.21	0.21
S O3	0.02	0.07	---
Total	106.2		

(a) Concentrations (wt.%) on an ash basis.

(b) Concentrations normalized to a closure of 100%.

(c) Concentrations renormalized to a SO3-free basis.

Comments:

TOTAL NUMBER OF POINTS = 250.0

SILICATE AND OTHER CRYSTALLINE PHASES

AKERMANITE	=	.0
% GEHLENITE	=	.0
% ANORTHITE	=	.0
% ALBITE	=	.0
% NEPHELINE	=	.0
% LEUCITE	=	.0
% POTASSIUM FELDSPAR	=	.0
% PYROXENE	=	.0
% MULLITE	=	.0
% MERWINITE	=	.0
% CALCIUM SILICATE	=	.0
% (CA,MG,FE)SIO3	=	.0
% DICALCIUM SILICATE	=	.0
% SPURRITE	=	.0
% NA2CASIO4	=	.0
% HAUYNE	=	.0
% CALCIUM ALUMINATE	=	.0
% SPINEL	=	.0
% CALCIUM TITANATE	=	.0

OXIDE OR CARBONATE PHASES

% QUARTZ	=	12.8
% IRON OXIDE	=	8.8
% CALCIUM OXIDE	=	.0
% MAGNESIUM OXIDE	=	.0
% ANKERITE (CA,MG,FE)CO3	=	.0
% ALUMINUM OXIDE	=	.0
RUTILE	=	.0
% DOLOMITE	=	.0

SULFATE AND SULFIDE PHASES

% BARITE	=	.0
% ANHYDRITE	=	.0
% SULFATED DOLOMITE	=	.0
% SULFATED ANKERITE	=	.0
% SODIUM SULFATE	=	.0
% SODIUM CALCIUM SULFATE	=	.0
% FERRIC SULFATE	=	.0
% PYRRHOTITE	=	.0
% PYRITE	=	.0

UNCLASSIFIED AND DESIGNATED AMORPHOUS PHASES

% UNCLASSIFIED	=	49.6
% PURE KAOLINITE (AMORP)	=	6.0
% KAOLINITE DERIVED	=	7.6
% ILLITE (AMORP)	=	6.0
% MONTMORILLONITE (AMORP)	=	9.2

THE FOLLOWING ARE ODD CRYSTALLINE PHASES

% APATITE	=	.0
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CALCIUM DERIVED POINTS

% CALCIUM DERIVED	=	.0
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CHEMICAL COMPOSITION WT %

	SIO2	AL2O3	FE2O3	TIO2	P2O5	CAO	MGO	NA2O	K2O	SO3	BAO	CR2O3	CLO
BULK	55.8	20.8	16.0	.7	.1	2.1	.8	.4	2.0	.6	.0	.4	.3
AMORP.	56.2	25.9	10.5	.8	.1	2.5	1.0	.4	2.4	.0	.0	.1	.0

SUMMARY OF CCSEM RESULTS: PROG VERSION 2BF 8/21/90

SAMPLE DESCRIPTION ---> CCTI-Watson:JDR Coal Low XS-Air Tst4 Inflamm Slds L1-3
 SUBMITTER ---> CZ
 CC # AND FUND # ---> 53193181
 RUN DATE AND TIME ---> 10 23 1991 11:26

SUMMARY OF PARAMETERS

TOTAL MINERAL AREA ANALYZED AT HIGH MAG = 6866.9
 NORMALIZED AREA ANALYZED AT HIGH MAG = 1631163.0
 TOTAL MINERAL AREA ANALYZED AT LOW MAG = 86225.4
 FIELD SIZE USED AT HIGH MAG = 115519.773
 FIELD SIZE USED AT LOW MAG = 2494610.477
 NUMBER OF FRAMES AT HIGH MAG = 3
 NUMBER OF FRAMES AT LOW MAG = 33
 TOTAL NUMBER OF POINTS ANALYZED = 1789
 NUMBER OF POINTS UNDER THRESHOLD = 5

WEIGHT PERCENT ON A MINERAL BASIS

	1.0 TO 2.2	2.2 TO 4.6	4.6 TO 10.0	10.0 TO 22.0	22.0 TO 46.0	46.0 TO 100.0	TOTALS
QUARTZ	1.7	6.5	5.2	1.2	.0	.0	14.7
IRON OXIDE	.3	2.7	1.2	.2	.2	.0	4.6
PERICLASE	.0	.0	.0	.0	.0	.0	.0
RUTILE	.0	.0	.0	.0	.0	.0	.0
ALUMINA	.0	.0	.0	.0	.0	.0	.0
CALCITE	.0	.2	.0	.0	.0	.0	.2
DOLOMITE	.0	.0	.0	.0	.0	.0	.0
ANKERITE	.1	.0	.3	.0	.0	.0	.4
KAOLINITE	1.4	5.8	1.6	.4	.0	.0	9.2
MONTMORILLONITE	.7	2.3	3.7	.2	.0	.0	6.9
K AL-SILICATE	.4	2.8	1.6	.2	.0	.0	5.1
FE AL-SILICATE	7.8	12.2	2.8	.4	.0	.0	23.2
CA AL-SILICATE	.2	.5	.2	.1	.0	.0	.9
NA AL-SILICATE	.0	.0	.0	.0	.0	.0	.0
ALUMINOSILICATE	.3	1.7	2.2	.2	.0	.0	4.5
MIXED AL-SILICA	.9	.6	.3	.1	.0	.0	1.8
FE SILICATE	.1	.8	.8	.2	.0	.0	1.8
CA SILICATE	.0	.0	.0	.0	.0	.0	.0
CA ALUMINATE	.0	.0	.0	.0	.0	.0	.0
PYRITE	.0	.0	.0	.0	.0	.0	.0
PYRRHOTITE	.0	.0	.0	.0	.0	.0	.0
OXIDIZED PYRRHO	.1	.3	.6	.0	.0	.0	1.0
GYPSUM	.0	.0	.0	.0	.0	.0	.0
BARITE	.0	.0	.0	.0	.0	.0	.0
APATITE	.0	.0	.0	.0	.0	.0	.0
CA AL-P	.0	.0	.0	.0	.0	.0	.0
KCL	.0	.0	.0	.0	.0	.0	.0
GYPSUM/BARITE	.0	.0	.0	.0	.0	.0	.0
GYPSUM/AL-SILIC	.0	.0	.0	.0	.0	.0	.0
SI-RICH	.7	2.9	1.6	.5	.0	.0	5.7
CA-RICH	.0	.0	.0	.0	.0	.0	.1
CA-SI RICH	.0	.0	.0	.0	.0	.0	.0
UNKNOWN	4.8	9.3	4.7	.8	.3	.0	19.9
TOTALS	19.5	48.5	26.9	4.5	.6	.0	100.0

ENERGY & ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
X-RAY POWDER DIFFRACTION REPORT

P.I.: Zygarlicke DATE: 7-25-91 ICC#: 53193009.XRD

SAMPLE DESCRIPTION: CCTI-Watson: Island Creek Baseline Coal
Test 4 Inflamm Solids L1-3

MAJOR PHASE(S):

Ferrite Spinel

Quartz

NOMINAL COMPOSITION(S):

(Mg, Fe) (Fe, Al)₂O₄

SiO₂

MINOR PHASE(S):

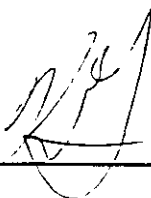
Mullite

NOMINAL COMPOSITION(S):

Al₆Si₄O₁₃

COMMENTS: Spurious peaks at 16.4 and 50.5 degrees two-theta are produced by contamination from the instrument.

Analyzed by

A handwritten signature, possibly reading 'N. H.', is written over a horizontal line.

ENERGY AND ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
EDXRF ANALYSIS REPORT

Date: 30-JUL-91

Inorganic Cost Center Number: 53193009

Coal Laboratory Number: 91-1192

Sample Description: Island Cr. BC T4 Inflamm Sol. L1-3

Sample Submitter: Zygarlicke

Analyst: Kevin Galbreath

Oxides (wt.%)	(a)	(b)	(c)
-----	----	----	----
SiO2	47.5	47.9	48.7
Al2O3	22.6	22.8	23.2
Fe2O3	16.9	17.1	17.3
TiO2	1.14	1.14	1.16
P2O5	0.25	0.25	0.26
CaO	3.99	4.02	4.09
MgO	1.14	1.15	1.17
Na2O	1.10	1.11	1.12
K2O	2.80	2.82	2.87
S O3	1.68	1.70	---
Total	99.1		

(a) Concentrations (wt.%) on an ash basis.

(b) Concentrations normalized to a closure of 100%.

(c) Concentrations renormalized to a SO3-free basis.

Comments:

SUMMARY OF CCSEM RESULTS: PROG VERSION 2BF 8/21/90

SAMPLE DESCRIPTION ----> 53193009.CCS CCTI-WAT:ISL CRK BASELINE COAL TST4 INFLAME SOL L1-
 SUBMITTER ----> ZYGARLICHE
 ICC # AND FUND # ----> 53193009
 RUN DATE AND TIME ----> 9 23 1991 13:58

SUMMARY OF PARAMETERS

TOTAL MINERAL AREA ANALYZED AT HIGH MAG = 16144.2
 NORMALIZED AREA ANALYZED AT HIGH MAG = 13945170.0
 TOTAL MINERAL AREA ANALYZED AT LOW MAG = 34758.3
 FIELD SIZE USED AT HIGH MAG = 115519.773
 FIELD SIZE USED AT LOW MAG = 2494610.477
 NUMBER OF FRAMES AT HIGH MAG = 1
 NUMBER OF FRAMES AT LOW MAG = 40
 TOTAL NUMBER OF POINTS ANALYZED = 3425
 NUMBER OF POINTS UNDER THRESHOLD = 7

WEIGHT PERCENT ON A MINERAL BASIS

	1.0 TO 2.2	2.2 TO 4.6	4.6 TO 10.0	10.0 TO 22.0	22.0 TO 46.0	46.0 TO 100.0	TOTALS
QUARTZ	1.3	6.1	5.0	.1	.0	.0	12.5
IRON OXIDE	.2	.6	.2	.0	.0	.0	1.1
PERICLASE	.0	.0	.0	.0	.0	.0	.0
RUTILE	.0	.0	.0	.0	.0	.0	.0
ALUMINA	.0	.0	.0	.0	.0	.0	.0
CALCITE	.0	.0	.0	.0	.0	.0	.0
DOLOMITE	.0	.0	.0	.0	.0	.0	.0
ANKERITE	.0	.0	.0	.0	.0	.0	.0
KAOLINITE	3.4	11.5	3.0	.0	.0	.0	17.9
MONTMORILLONITE	1.9	5.1	2.0	.0	.0	.0	9.0
K AL-SILICATE	2.1	3.6	1.5	.0	.0	.0	7.1
FE AL-SILICATE	8.0	12.4	1.2	.0	.0	.0	21.7
CA AL-SILICATE	.6	2.1	.7	.0	.0	.0	3.3
NA AL-SILICATE	.1	.0	.1	.0	.0	.0	.2
ALUMINOSILICATE	.4	1.0	1.8	.0	.0	.0	3.2
MIXED AL-SILICA	2.3	3.7	.5	.0	.0	.0	6.5
FE SILICATE	.1	.3	.0	.0	.0	.0	.5
CA SILICATE	.0	.0	.1	.0	.0	.0	.1
CA ALUMINATE	.0	.1	.0	.0	.0	.0	.1
PYRITE	.0	.0	.0	.0	.0	.0	.0
PYRRHOTITE	.0	.0	.0	.0	.0	.0	.0
OXIDIZED PYRRHO	.0	.2	.0	.0	.0	.0	.2
GYPSUM	.0	.0	.0	.0	.0	.0	.0
BARITE	.0	.0	.0	.0	.0	.0	.0
APATITE	.0	.1	.0	.0	.0	.0	.1
CA AL-P	.0	.0	.0	.0	.0	.0	.0
KCL	.0	.0	.0	.0	.0	.0	.0
GYPSUM/BARITE	.0	.0	.0	.0	.0	.0	.0
GYPSUM/AL-SILIC	.1	.2	.3	.0	.0	.0	.6
SI-RICH	.8	2.1	.3	.0	.0	.0	3.2
CA-RICH	.0	.3	.3	.0	.0	.0	.5
CA-SI RICH	.0	.1	.0	.0	.0	.0	.1
UNKNOWN	4.0	6.3	1.8	.0	.0	.0	12.1
TOTALS	25.4	55.8	18.5	.2	.0	.0	100.0

ENERGY & ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
X-RAY POWDER DIFFRACTION REPORT

P.I.: Zygarlicke DATE: 7-25-91 ICC#: 53193010.XRD

SAMPLE DESCRIPTION: CCTI-Watson: Island Creek Baseline Coal
Test 4 Inflamm Solids L1-18

MAJOR PHASE(S):

NOMINAL COMPOSITION(S):

Ferrite Spinel

(Mg, Fe) (Fe, Al)₂O₄

Quartz

SiO₂

MINOR PHASE(S):

NOMINAL COMPOSITION(S):

Bassanite

CaSO₄ · 0.5H₂O

Anhydrite

CaSO₄

COMMENTS:

Analyzed by



ENERGY AND ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
EDXRF ANALYSIS REPORT

Date: 30-JUL-91

Inorganic Cost Center Number: 53193010

Coal Laboratory Number: 91-1193

Sample Description: Island Cr. BC T4 Inflamm Sol. L1-18

Sample Submitter: Zygarlicke

Analyst: Kevin Galbreath

Oxides (wt.%)	(a)	(b)	(c)
-----	----	----	----
SiO2	47.2	47.0	48.1
Al2O3	21.8	21.7	22.2
Fe2O3	18.0	17.9	18.4
TiO2	1.05	1.05	1.08
P2O5	0.29	0.29	0.30
CaO	4.79	4.78	4.90
MgO	1.18	1.18	1.21
Na2O	1.06	1.06	1.08
K2O	2.59	2.58	2.65
S O3	2.44	2.43	---
Total	100.4		

(a) Concentrations (wt.%) on an ash basis.

(b) Concentrations normalized to a closure of 100%.

(c) Concentrations renormalized to a SO3-free basis.

Comments:

ENERGY & ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
X-RAY POWDER DIFFRACTION REPORT

P.I.: Zygarlicke DATE: 7-26-91 ICC#: 53193012.XRD

SAMPLE DESCRIPTION: CCTI-Watson: Island Creek Baseline Coal Test 4
WW Panel 1 Outer

MAJOR PHASE(S):

Hematite

Ferrite Spinel

NOMINAL COMPOSITION(S):

Fe_2O_3

$(\text{Mg}, \text{Fe})(\text{Fe}, \text{Al})_2\text{O}_4$

MINOR PHASE(S):

Anhydrite

Quartz

Plagioclase

NOMINAL COMPOSITION(S):

CaSO_4

SiO_2

$(\text{Ca}, \text{Na})(\text{Si}, \text{Al})_4\text{O}_8$

COMMENTS:

Analyzed by  _____

ENERGY AND ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
EDXRF ANALYSIS REPORT

Date: 30-JUL-91

Inorganic Cost Center Number: 53193012

Coal Laboratory Number: 91-1195

Sample Description: Island Cr. BC T4 WW Panel 1 Outer

Sample Submitter: Zygarlicke

Analyst: Kevin Galbreath

Oxides (wt.%)	(a)	(b)	(c)
-----	----	----	----
SiO2	47.6	45.5	45.6
Al2O3	18.1	17.3	17.4
Fe2O3	28.3	27.0	27.1
TiO2	0.81	0.77	0.77
P2O5	0.34	0.33	0.33
CaO	4.89	4.66	4.68
MgO	1.11	1.06	1.07
Na2O	0.91	0.87	0.87
K2O	2.21	2.11	2.12
S O3	0.44	0.42	---
Total	104.8		

(a) Concentrations (wt.%) on an ash basis.

(b) Concentrations normalized to a closure of 100%.

(c) Concentrations renormalized to a SO3-free basis.

Comments:

TOTAL NUMBER OF POINTS = 250.0

SILICATE AND OTHER CRYSTALLINE PHASES

ANKERMANITE	=	.0
GEHLENITE	=	.0
% ANORTHITE	=	3.6
% ALBITE	=	.0
% NEPHELINE	=	.0
% LEUCITE	=	.0
% POTASSIUM FELDSPAR	=	.0
% PYROXENE	=	.0
% MULLITE	=	.0
% MERWINITE	=	.0
% CALCIUM SILICATE	=	.0
% (CA,MG,FE) SIO3	=	.0
% DICALCIUM SILICATE	=	.0
% SPURRITE	=	.0
% NA2CASIO4	=	.0
% HAUYNE	=	.0
% CALCIUM ALUMINATE	=	.0
% SPINEL	=	.0
% CALCIUM TITANATE	=	.0

OXIDE OR CARBONATE PHASES

% QUARTZ	=	5.6
% IRON OXIDE	=	10.8
% CALCIUM OXIDE	=	.0
% MAGNESIUM OXIDE	=	.0
% ANKERITE (CA,MG,FE) CO3	=	.0
% ALUMINUM OXIDE	=	.0
% RUTILE	=	.0
% DOLOMITE	=	.0

SULFATE AND SULFIDE PHASES

% BARITE	=	.0
% ANHYDRITE	=	1.2
% SULFATED DOLOMITE	=	.0
% SULFATED ANKERITE	=	.0
% SODIUM SULFATE	=	.0
% SODIUM CALCIUM SULFATE	=	.0
% FERRIC SULFATE	=	.0
% PYRRHOTITE	=	.0
% PYRITE	=	.0

UNCLASSIFIED AND DESIGNATED AMORPHOUS PHASES

% UNCLASSIFIED	=	53.6
% PURE KAOLINITE (AMORP)	=	1.2
% KAOLINITE DERIVED	=	7.2
% ILLITE (AMORP)	=	5.6
% MONTMORILLONITE (AMORP)	=	11.2

THE FOLLOWING ARE ODD CRYSTALLINE PHASES

% APATITE	=	.0
-----------	---	----

CALCIUM DERIVED POINTS

% CALCIUM DERIVED	=	.0
-------------------	---	----

CHEMICAL COMPOSITION WT %

	SIO2	AL2O3	FE2O3	TIO2	P2O5	CAO	MGO	NA2O	K2O	SO3	BAO	CR2O3	CLO
BULK	46.9	18.3	20.7	1.2	.5	4.6	.8	1.3	2.8	2.2	.0	.1	.5
AMORP.	51.9	22.0	14.2	1.4	.7	3.6	1.0	1.6	3.5	.0	.0	.1	.0

ENERGY & ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
X-RAY POWDER DIFFRACTION REPORT

P.I.: Zygarlicke DATE: 7-25-91 ICC#: 53193013.XRD

SAMPLE DESCRIPTION: CCTI-Watson: Island Creek Baseline Coal
Test 4 WW Panel 1 Inner

MAJOR PHASE(S):

Hematite

Anhydrite

Quartz

NOMINAL COMPOSITION(S):

Fe_2O_3

CaSO_4

SiO_2

MINOR PHASE(S):

Ferrite Spinel (Magnetite)

Mullite

Plagioclase

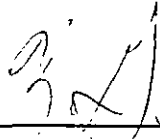
NOMINAL COMPOSITION(S):

$(\text{Mg}, \text{Fe})(\text{Fe}, \text{Al})_2\text{O}_4$

$\text{Al}_6\text{Si}_4\text{O}_{13}$

$(\text{Ca}, \text{Na})(\text{Si}, \text{Al})_4\text{O}_8$

COMMENTS:

Analyzed by 

ENERGY AND ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH CAROLINA
EDXRF ANALYSIS REPORT

Date: 29-JUL-91

Inorganic Cost Center Number: 53193013

Coal Laboratory Number: 91-1196

Sample Description: Island Cr. SC T4 WW Panel 1 Inner

Sample Submitter: Zygarlicke

Analyst: Kevin Galbreath

Oxides (wt.%)	(a)	(b)	(c)
-----	----	----	----
SiO2	43.3	43.3	44.9
Al2O3	19.2	19.2	19.9
Fe2O3	21.3	21.3	22.1
TiO2	0.86	0.86	0.89
P2O5	0.70	0.70	0.73
CaO	5.29	5.28	5.48
MgO	1.32	1.32	1.37
Na2O	1.14	1.14	1.19
K2O	3.30	3.29	3.42
S O3	3.64	3.63	---
Total	100.1		

(a) Concentrations (wt.%) on an ash basis.

(b) Concentrations normalized to a closure of 100%.

(c) Concentrations renormalized to a SO3-free basis.

Comments:

TOTAL NUMBER OF POINTS = 250.0

SILICATE AND OTHER CRYSTALLINE PHASES

AKERMANITE = .0
GEHLENITE = .0
% ANORTHITE = 2.4
% ALBITE = .0
% NEPHELINE = .0
% LEUCITE = .0
% POTASSIUM FELDSPAR = .0
% PYROXENE = .0
% MULLITE = .0
% MERWINITE = .0
% CALCIUM SILICATE = .0
% (CA,MG,FE)SIO3 = .0
% DICALCIUM SILICATE = .0
% SPURRITE = .0
% NA2CASIO4 = .0
% HAUYNE = .0
% CALCIUM ALUMINATE = .0
% SPINEL = .0
% CALCIUM TITANATE = .0

OXIDE OR CARBONATE PHASES

% QUARTZ = 9.2
% IRON OXIDE = 3.6
% CALCIUM OXIDE = .0
% MAGNESIUM OXIDE = .0
% ANKERITE (CA,MG,FE)CO3 = .0
% ALUMINUM OXIDE = .0
% RUTILE = .0
% DOLOMITE = .0

SULFATE AND SULFIDE PHASES

% BARITE = .0
% ANHYDRITE = 2.0
% SULFATED DOLOMITE = .0
% SULFATED ANKERITE = .0
% SODIUM SULFATE = .0
% SODIUM CALCIUM SULFATE = .0
% FERRIC SULFATE = .0
% PYRRHOTITE = .0
% PYRITE = .0

UNCLASSIFIED AND DESIGNATED AMORPHOUS PHASES

% UNCLASSIFIED = 60.0
% PURE KAOLINITE (AMORP) = 2.4
% KAOLINITE DERIVED = 7.6
% ILLITE (AMORP) = 6.8
% MONTMORILLONITE (AMORP) = 5.2

THE FOLLOWING ARE ODD CRYSTALLINE PHASES

% APATITE = .4

CALCIUM DERIVED POINTS

% CALCIUM DERIVED = .4

CHEMICAL COMPOSITION WT %

	SIO2	AL2O3	FE2O3	TIO2	P2O5	CAO	MGO	NA2O	K2O	SO3	BAO	CR2O3	CLO
BULK	47.1	18.6	11.8	1.4	.5	4.5	.9	1.6	3.4	8.5	.0	.1	1.5
AMORP.	50.5	23.8	11.4	1.7	.5	4.5	1.1	2.0	4.4	.0	.0	.2	.0

ENERGY & ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
X-RAY POWDER DIFFRACTION REPORT

P.I.: Zygarlicke DATE: 7-30-91 ICC#: 53193014.XRD

SAMPLE DESCRIPTION: CCTI-Watson: Island Creek Baseline Coal
Test 4 WW Panel 4 Outer

MAJOR PHASE(S):

Hematite

NOMINAL COMPOSITION(S):

Fe_2O_3

MINOR PHASE(S):

Plagioclase

Quartz

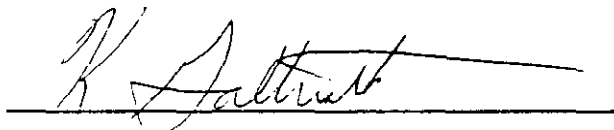
NOMINAL COMPOSITION(S):

$(\text{Ca}, \text{Na})(\text{Si}, \text{Al})_4\text{O}_8$

SiO_2

COMMENTS:

Analyzed by



ENERGY AND ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
EDXRF ANALYSIS REPORT

Date: 30-JUL-91

Inorganic Cost Center Number: 53193014

Coal Laboratory Number: 91-1197

Sample Description: Island Cr. BC T4 WW Panel 4 Outer

Sample Submitter: Zygarlicke

Analyst: Kevin Galbreath

Oxides (wt.%)	(a)	(b)	(c)
-----	----	----	----
SiO2	47.9	45.8	46.0
Al2O3	18.3	17.5	17.6
Fe2O3	29.1	26.8	26.9
TiO2	0.77	0.73	0.74
P2O5	0.39	0.37	0.37
CaO	4.68	4.47	4.49
MgO	1.06	1.01	1.02
Na2O	0.70	0.67	0.67
K2O	2.27	2.17	2.18
S O3	0.47	0.45	---
Total	104.7		

(a) Concentrations (wt.%) on an ash basis.

(b) Concentrations normalized to a closure of 100%.

(c) Concentrations renormalized to a SO3-free basis.

Comments:

ENERGY & ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
X-RAY POWDER DIFFRACTION REPORT

P.I.: Zygarlicke DATE: 7-25-91 ICC#: 53193015.XRD

SAMPLE DESCRIPTION: CCTI-Watson: Island Creek Baseline Coal
Test 4 WW Panel 4 Inner

MAJOR PHASE(S):

NOMINAL COMPOSITION(S):

Hematite

Fe_2O_3

Anhydrite

CaSO_4

Quartz

SiO_2

Ferrite Spinel

$(\text{Mg}, \text{Fe})(\text{Fe}, \text{Al})_2\text{O}_4$

MINOR PHASE(S):

NOMINAL COMPOSITION(S):

Possible Plagioclase

$(\text{Ca}, \text{Na})(\text{Si}, \text{Al})_4\text{O}_8$

COMMENTS:

Analyzed by 

ENERGY AND ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
EDXRF ANALYSIS REPORT

Date: 29-JUL-91

Inorganic Cost Center Number: 53193015

Coal Laboratory Number: 91-1198

Sample Description: Island Cr. BC T4 WW Panel 4 Inner

Sample Submitter: Zygarlicke

Analyst: Kevin Galbreath

Oxides (wt.%) -----	(a) ----	(b) ----	(c) ----
SiO ₂	44.2	44.0	45.4
Al ₂ O ₃	18.6	18.5	19.1
Fe ₂ O ₃	25.2	25.0	25.9
TiO ₂	0.84	0.84	0.86
P ₂ O ₅	0.46	0.46	0.47
CaO	3.92	3.90	4.03
MgO	1.27	1.26	1.30
Na ₂ O	0.71	0.70	0.72
K ₂ O	2.19	2.18	2.25
S O ₃	3.17	3.15	---
Total	100.5		

(a) Concentrations (wt.%) on an ash basis.

(b) Concentrations normalized to a closure of 100%.

(c) Concentrations renormalized to a SO₃-free basis.

Comments:

ENERGY & ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
X-RAY POWDER DIFFRACTION REPORT

P.I.: Zygarlicke DATE: 7-25-91 ICC#: 53193018.XRD

SAMPLE DESCRIPTION: CCTI-Watson: Island Creek Baseline Coal Test SH
Probe 1A Outer

MAJOR PHASE(S):

Hematite

Quartz

NOMINAL COMPOSITION(S):

Fe_2O_3

SiO_2

MINOR PHASE(S):

Mullite

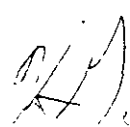
Anhydrite

NOMINAL COMPOSITION(S):

$\text{Al}_6\text{Si}_4\text{O}_{13}$

CaSO_4

COMMENTS: Unable to account for the peak at a d-spacing of 2.43.

Analyzed by 

ENERGY AND ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
EDXRF ANALYSIS REPORT

Date: 30-JUL-91

Inorganic Cost Center Number: 53193018

Coal Laboratory Number: 91-1201

Sample Description: Island Cr. BC SH Probe 1A Outer

Sample Submitter: Zygarlicke

Analyst: Kevin Galbreath

Oxides (wt.%)	(a)	(b)	(c)
-----	----	----	----
SiO2	42.2	43.3	43.7
Al2O3	18.6	19.1	19.3
Fe2O3	27.2	27.9	28.1
TiO2	1.10	1.12	1.13
P2O5	0.18	0.18	0.18
CaO	4.14	4.24	4.28
MgO	1.14	1.17	1.18
Na2O	0.52	0.53	0.54
K2O	1.65	1.69	1.70
S O3	0.79	0.81	---
Total	97.5		

(a) Concentrations (wt.%) on an ash basis.

(b) Concentrations normalized to a closure of 100%.

(c) Concentrations renormalized to a SO3-free basis.

Comments:

TOTAL NUMBER OF POINTS = 250.0
SILICATE AND OTHER CRYSTALLINE PHASES

AKERMANITE = .0
GEHLENITE = .0
% ANORTHITE = 1.6
% ALBITE = .0
% NEPHELINE = .0
% LEUCITE = .0
% POTASSIUM FELDSPAR = .0
% PYROXENE = .0
% MULLITE = .0
% MERWINITE = .0
% CALCIUM SILICATE = .0
% (CA,MG,FE)SIO3 = .0
% DICALCIUM SILICATE = .0
% SPURRITE = .0
% NA2CASIO4 = .0
% HAUYNE = .0
% CALCIUM ALUMINATE = .0
% SPINEL = .0
% CALCIUM TITANATE = .0

OXIDE OR CARBONATE PHASES
% QUARTZ = 10.4
% IRON OXIDE = 6.4
% CALCIUM OXIDE = .0
% MAGNESIUM OXIDE = .0
% ANKERITE (CA,MG,FE)CO3 = .0
% ALUMINUM OXIDE = .0
% RUTILE = .0
% DOLOMITE = .0

SULFATE AND SULFIDE PHASES
% BARITE = .0
% ANHYDRITE = .0
% SULFATED DOLOMITE = .0
% SULFATED ANKERITE = .0
% SODIUM SULFATE = .0
% SODIUM CALCIUM SULFATE = .0
% FERRIC SULFATE = .0
% PYRRHOTITE = .0
% PYRITE = .0

UNCLASSIFIED AND DESIGNATED AMORPHOUS PHASES
% UNCLASSIFIED = 58.0
% PURE KAOLINITE (AMORP) = 2.0
% KAOLINITE DERIVED = 10.8
% ILLITE (AMORP) = 4.0
% MONTMORILLONITE (AMORP) = 6.8

THE FOLLOWING ARE ODD CRYSTALLINE PHASES
% APATITE = .0

CALCIUM DERIVED POINTS
% CALCIUM DERIVED = .0

CHEMICAL COMPOSITION WT %

	SIO2	AL2O3	FE2O3	TIO2	P2O5	CAO	MGO	NA2O	K2O	SO3	BAO	CR2O3	CLO
BULK	52.1	21.2	15.6	1.1	.2	3.7	.9	1.2	2.2	1.1	.0	.1	.6
AMORP.	51.2	25.2	12.5	1.3	.2	4.6	1.0	1.4	2.6	.0	.0	.1	.0

ENERGY & ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
X-RAY POWDER DIFFRACTION REPORT

P.I.: Zygarlicke DATE: 7-25-91 ICC#: 53193019.XRD

SAMPLE DESCRIPTION: CCTI-Watson: Island Creek Baseline Coal Test SH
Probe 1A Inner

MAJOR PHASE(S):

NOMINAL COMPOSITION(S):

Hematite

Fe_2O_3

Anhydrite

CaSO_4

Ferrite Spinel

$(\text{Mg}, \text{Fe}) (\text{Fe}, \text{Al})_2\text{O}_4$

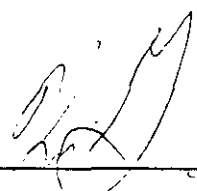
MINOR PHASE(S):

NOMINAL COMPOSITION(S):

Quartz

SiO_2

COMMENTS:

Analyzed by  _____

ENERGY AND ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
EDXRF ANALYSIS REPORT

Date: 30-JUL-91

Inorganic Cost Center Number: 53193019

Coal Laboratory Number: 91-1202

Sample Description: Island Cr. BC SH Probe 1A Inner

Sample Submitter: Zygarlicko

Analyst: Kevin Galbreath

Oxides (wt.%)	(a)	(b)	(c)
-----	----	----	----
SiO2	23.5	24.0	25.0
Al2O3	10.8	11.0	11.5
Fe2O3	51.0	52.0	54.2
TiO2	0.82	0.84	0.86
P2O5	0.50	0.51	0.54
CaO	5.37	5.48	5.72
MgO	0.77	0.79	0.82
Na2O	0.30	0.30	0.32
K2O	0.86	0.80	0.91
S O3	4.04	4.13	---
Total	98.0		

(a) Concentrations (wt.%) on an ash basis.

(b) Concentrations normalized to a closure of 100%.

(c) Concentrations renormalized to a SO3-free basis.

Comments:

TOTAL NUMBER OF POINTS = 250.0

SILICATE AND OTHER CRYSTALLINE PHASES

AKERMANITE	=	.0
GEHLENITE	=	.0
% ANORTHITE	=	.0
% ALBITE	=	.0
% NEPHELINE	=	.0
% LEUCITE	=	.0
% POTASSIUM FELDSPAR	=	.0
% PYROXENE	=	2.0
% MULLITE	=	.0
% MERWINITE	=	.0
% CALCIUM SILICATE	=	.0
% (CA,MG,FE)SIO3	=	.0
% DICALCIUM SILICATE	=	.0
% SPURRITE	=	.0
% NA2CASIO4	=	.0
% HAUZYNE	=	.0
% CALCIUM ALUMINATE	=	.0
% SPINEL	=	.0
% CALCIUM TITANATE	=	.0

OXIDE OR CARBONATE PHASES

% QUARTZ	=	5.2
% IRON OXIDE	=	37.6
% CALCIUM OXIDE	=	.0
% MAGNESIUM OXIDE	=	.0
% ANKERITE (CA,MG,FE)CO3	=	.0
% ALUMINUM OXIDE	=	.0
% RUTILE	=	.0
% DOLOMITE	=	.0

SULFATE AND SULFIDE PHASES

% BARITE	=	.0
% ANHYDRITE	=	3.2
% SULFATED DOLOMITE	=	.0
% SULFATED ANKERITE	=	.0
% SODIUM SULFATE	=	.0
% SODIUM CALCIUM SULFATE	=	.0
% FERRIC SULFATE	=	.0
% PYRRHOTITE	=	.0
% PYRITE	=	.0

UNCLASSIFIED AND DESIGNATED AMORPHOUS PHASES

% UNCLASSIFIED	=	46.8
% PURE KAOLINITE (AMORP)	=	.4
% KAOLINITE DERIVED	=	.8
% ILLITE (AMORP)	=	1.6
% MONTMORILLONITE (AMORP)	=	.8

THE FOLLOWING ARE ODD CRYSTALLINE PHASES

% APATITE	=	.8
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CALCIUM DERIVED POINTS

% CALCIUM DERIVED	=	.8
-------------------	---	----

CHEMICAL COMPOSITION WT %

	SIO2	AL2O3	FE2O3	TIO2	P2O5	CAO	MGO	NA2O	K2O	SO3	BAO	CR2O3	CLO
BULK	31.8	11.3	42.6	.7	.6	5.0	.9	.9	1.2	4.1	.0	.2	.8
AMORP.	48.6	20.8	20.2	1.3	.3	3.9	.9	1.3	2.4	.0	.0	.2	.0

SUMMARY OF CCSEM RESULTS: PROG VERSION 2BF 8/21/90

SAMPLE DESCRIPTION ----> ZYG CCTI-Watson:ISL Crk BL Coal Test 4 Infl Slds SH 1A
 SUBMITTER ----> CZ
 ICC # AND FUND # ----> 53193020
 RUN DATE AND TIME ----> 10 23 1991 10:31

SUMMARY OF PARAMETERS

TOTAL MINERAL AREA ANALYZED AT HIGH MAG = 7498.6
 NORMALIZED AREA ANALYZED AT HIGH MAG = 998566.8
 TOTAL MINERAL AREA ANALYZED AT LOW MAG = 26700.8
 FIELD SIZE USED AT HIGH MAG = 115519.773
 FIELD SIZE USED AT LOW MAG = 2494610.477
 NUMBER OF FRAMES AT HIGH MAG = 6
 NUMBER OF FRAMES AT LOW MAG = 37
 TOTAL NUMBER OF POINTS ANALYZED = 1311
 NUMBER OF POINTS UNDER THRESHOLD = 3

WEIGHT PERCENT ON A MINERAL BASIS

	1.0 TO 2.2	2.2 TO 4.6	4.6 TO 10.0	10.0 TO 22.0	22.0 TO 46.0	46.0 TO 100.0	TOTALS
QUARTZ	1.0	6.4	5.7	.8	.0	.0	13.9
IRON OXIDE	.0	3.2	2.4	.0	.3	.0	5.9
PERICLASE	.0	.0	.0	.0	.0	.0	.0
RUTILE	.0	.0	.0	.0	.0	.0	.0
ALUMINA	.0	.0	.0	.0	.2	.0	.2
CALCITE	.0	.3	.4	.0	.0	.0	.7
DOLOMITE	.0	.0	.0	.0	.0	.0	.0
ANKERITE	.0	.0	.0	.0	.0	.0	.0
KAOLINITE	2.0	7.7	2.5	.1	.0	.0	12.3
MONTMORILLONITE	.8	4.1	.9	.2	.0	.0	6.1
K AL-SILICATE	1.0	5.7	2.6	.3	.0	.0	9.7
FE AL-SILICATE	5.7	11.6	2.6	.1	.0	.0	20.0
CA AL-SILICATE	.3	1.7	.2	.0	.0	.0	2.2
NA AL-SILICATE	.0	.0	.0	.0	.0	.0	.0
ALUMINOSILICATE	.3	.8	.2	.1	.0	.0	1.5
MIXED AL-SILICA	1.6	3.5	.7	.0	.0	.0	5.8
FE SILICATE	.1	.2	.0	.0	.0	.0	.3
CA SILICATE	.0	.0	.0	.0	.0	.0	.0
CA ALUMINATE	.0	.3	.0	.0	.0	.0	.3
PYRITE	.0	.0	.0	.0	.0	.0	.0
PYRRHOTITE	.0	.0	.0	.0	.0	.0	.0
OXIDIZED PYRRHO	.1	.3	.0	.0	.0	.0	.4
GYPNUM	.0	.0	.0	.0	.0	.0	.0
BARITE	.0	.0	.0	.0	.0	.0	.0
APATITE	.0	.0	.0	.0	.0	.0	.0
CA AL-P	.0	.0	.0	.0	.0	.0	.0
KCL	.0	.0	.0	.0	.0	.0	.0
GYPNUM/BARITE	.0	.0	.0	.0	.0	.0	.0
GYPNUM/AL-SILIC	.0	.0	.0	.0	.0	.0	.0
SI-RICH	.6	2.5	.7	.2	.0	.0	4.0
CA-RICH	.0	.8	.2	.0	.0	.0	1.0
CA-SI RICH	.0	.0	.0	.0	.0	.0	.0
UNKNOWN	2.7	9.5	3.2	.2	.0	.0	15.7
TOTALS	16.3	58.5	22.5	2.2	.6	.0	100.0

ENERGY & ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
X-RAY POWDER DIFFRACTION REPORT

P.I.: Zygarlicke DATE: 7-25-91 ICC#: 53192987.XRD

SAMPLE DESCRIPTION: CCTI-Watson: Island Creek Baseline Coal XS-Air
Test 4 Inflamm Solids L1-3

MAJOR PHASE(S):

Ferrite Spinel

Quartz

NOMINAL COMPOSITION(S):

(Mg,Fe)(Fe,Al)₂O₄

SiO₂

MINOR PHASE(S):

Possible Lime

NOMINAL COMPOSITION(S):

CaO

COMMENTS: Sample contains a large amount of amorphous component.

Analyzed by



ENERGY AND ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
EDXRF ANALYSIS REPORT

Date: 30-JUL-91

Inorganic Cost Center Number: 53192987

Coal Laboratory Number: 91-1210

Sample Description: Island Creek DC T4 Inflamm Sol. L1-3 XS-A₁₂

Sample Submitter: Zygarhoke

Analyst: Kevin Galbreath

Oxides (wt.%) -----	(a) ----	(b) ----	(c) ----
SiO ₂	45.5	45.7	46.7
Al ₂ O ₃	21.7	21.8	22.2
Fe ₂ O ₃	19.8	19.9	20.4
TiO ₂	1.10	1.10	1.13
P ₂ O ₅	0.31	0.31	0.31
CaO	4.34	4.36	4.45
MgO	1.00	1.00	1.03
Na ₂ O	0.92	0.92	0.94
K ₂ O	2.68	2.70	2.75
S O ₃	2.11	2.12	---
Total	99.6		

(a) Concentrations (wt.%) on an ash basis.

(b) Concentrations normalized to a closure of 100%.

(c) Concentrations renormalized to a SO₃-free basis.

Comments:

SUMMARY OF CCSEM RESULTS: PROG VERSION 2BF 8/21/90

SAMPLE DESCRIPTION ----> 53192987.CCS BASELINE COAL-XS AIR TEST 4 INFLAME SOLIDS 1-3
 SUBMITTER ----> ZYGARLICHE
 ICC # AND FUND # ----> 53192987
 RUN DATE AND TIME ----> 9 20 1991 15:18

SUMMARY OF PARAMETERS

TOTAL MINERAL AREA ANALYZED AT HIGH MAG = 7142.9
 NORMALIZED AREA ANALYZED AT HIGH MAG = 5552970.0
 TOTAL MINERAL AREA ANALYZED AT LOW MAG = 73574.2
 FIELD SIZE USED AT HIGH MAG = 115519.773
 FIELD SIZE USED AT LOW MAG = 2494610.477
 NUMBER OF FRAMES AT HIGH MAG = 1
 NUMBER OF FRAMES AT LOW MAG = 36
 TOTAL NUMBER OF POINTS ANALYZED = 2078
 NUMBER OF POINTS UNDER THRESHOLD = 6

WEIGHT PERCENT ON A MINERAL BASIS

	1.0 TO 2.2	2.2 TO 4.6	4.6 TO 10.0	10.0 TO 22.0	22.0 TO 46.0	46.0 TO 100.0	TOTALS
QUARTZ	2.0	5.4	2.3	.2	.0	.0	9.9
IRON OXIDE	.3	1.1	.5	.0	.0	.0	1.9
PERICLASE	.0	.0	.0	.0	.0	.0	.0
RUTILE	.0	.0	.0	.0	.0	.0	.0
ALUMINA	.0	.0	.0	.0	.0	.0	.0
CALCITE	.0	.0	.0	.0	.0	.0	.0
DOLOMITE	.0	.0	.0	.0	.0	.0	.0
ANKERITE	.0	.0	.0	.0	.0	.0	.0
KAOLINITE	3.6	8.3	2.7	.0	.0	.0	14.6
MONTMORILLONITE	1.5	3.2	2.0	.0	.0	.0	6.8
K AL-SILICATE	1.0	2.0	.9	.1	.0	.0	4.0
FE AL-SILICATE	10.7	13.7	2.3	.1	.0	.0	26.8
CA AL-SILICATE	.3	1.4	.0	.0	.0	.0	1.7
NA AL-SILICATE	.0	.0	.0	.0	.0	.0	.0
ALUMINOSILICATE	.3	.9	.9	.0	.0	.0	2.2
MIXED AL-SILICA	1.8	2.7	.5	.0	.0	.0	5.1
FE SILICATE	.2	.3	.0	.0	.0	.0	.5
CA SILICATE	.0	.0	.0	.0	.0	.0	.0
CA ALUMINATE	.0	.0	.0	.0	.0	.0	.0
PYRITE	.0	.0	.0	.0	.0	.0	.0
PYRRHOTITE	.0	.0	.0	.0	.0	.0	.0
OXIDIZED PYRRHO	.0	.2	.0	.0	.0	.0	.2
GYPSUM	.0	.0	.0	.1	.0	.0	.1
BARITE	.0	.0	.0	.0	.0	.0	.0
APATITE	.1	.0	.0	.0	.0	.0	.1
CA AL-P	.0	.0	.0	.0	.0	.0	.0
KCL	.0	.0	.0	.0	.0	.0	.0
GYPSUM/BARITE	.0	.0	.0	.0	.0	.0	.0
GYPSUM/AL-SILIC	.0	.5	.3	.0	.0	.0	.9
SI-RICH	.6	2.2	.5	.1	.0	.0	3.4
CA-RICH	.0	.3	.4	.0	.0	.0	.7
CA-SI RICH	.0	.0	.0	.0	.0	.0	.0
UNKNOWN	7.2	11.0	2.6	.4	.0	.0	21.3
TOTALS	29.5	53.2	15.9	1.2	.1	.0	100.0

ENERGY & ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
X-RAY POWDER DIFFRACTION REPORT

P.I.: Zygarlicke DATE: 7-25-91 ICC#: 53192988.XRD

SAMPLE DESCRIPTION: CCTI-Watson: Island Creek Baseline Coal XS-Air
Test 4 Inflamm Solids L1-18

MAJOR PHASE(S):

NOMINAL COMPOSITION(S):

Ferrite Spinel

$(\text{Mg, Fe}) (\text{Fe, Al})_2\text{O}_4$

Quartz

SiO_2

Possible Corundum

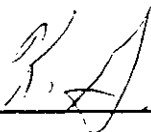
Al_2O_3

MINOR PHASE(S):

NOMINAL COMPOSITION(S):

COMMENTS: Sample contains a large amount of amorphous component.

Analyzed by



ENERGY AND ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
EDXRF ANALYSIS REPORT

Date: 30-JUL-91

Inorganic Cost Center Number: 53192988

Coal Laboratory Number: 91-1211

Sample Description: Island Cr. BC T4 Inflamm Sol. L1-18 XS-A12

Sample Submitter: Zygarlicke

Analyst: Kevin Galbreath

Oxides (wt.%) -----	(a) ----	(b) ----	(c) ----
SiO2	44.3	45.8	46.7
Al2O3	21.4	22.1	22.6
Fe2O3	19.2	19.8	20.2
TiO2	1.07	1.11	1.13
P2O5	0.29	0.30	0.31
CaO	4.21	4.35	4.44
MgO	0.90	0.93	0.95
Na2O	0.82	0.85	0.86
K2O	2.60	2.68	2.74
S O3	1.90	1.96	---
Total	96.8		

(a) Concentrations (wt.%) on an ash basis.

(b) Concentrations normalized to a closure of 100%.

(c) Concentrations renormalized to a SO3-free basis.

Comments:

ENERGY & ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
X-RAY POWDER DIFFRACTION REPORT

P.I.: Zygarlicke DATE: 7-25-91 ICC#: 53192990.XRD

SAMPLE DESCRIPTION: CCTI-Watson: Island Creek Baseline Coal XS-Air
Test 4 WW Panel 1 Outer

MAJOR PHASE(S):

Hematite

Quartz

NOMINAL COMPOSITION(S):

Fe_2O_3

SiO_2

MINOR PHASE(S):

Ferrite Spinel

Possible Plagioclase

NOMINAL COMPOSITION(S):

$(\text{Mg}, \text{Fe}) (\text{Fe}, \text{Al})_2\text{O}_4$

$(\text{Ca}, \text{Na}) (\text{Si}, \text{Al})_4\text{O}_8$

COMMENTS:

Analyzed by  _____

ENERGY AND ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
EDXRF ANALYSIS REPORT

Date: 31-JUL-91

Inorganic Cost Center Number: 53192990

Coal Laboratory Number: 91-1213

Sample Description: Island Cr. BC T4 WW Panel 1 Outer XS - Air

Sample Submitter: Zygarlicke

Analyst: Kevin Galbreath

Oxides (wt.%)	(a)	(b)	(c)
-----	-----	-----	-----
SiO2	47.0	46.5	46.5
AL2O3	18.1	17.8	17.9
O3	27.1	26.8	26.8
TiO2	0.78	0.77	0.77
P2O5	0.15	0.14	0.15
CaO	4.08	4.03	4.03
MgO	0.82	0.81	0.82
Na2O	0.82	0.81	0.81
K2O	2.29	2.26	2.26
S O3	0.09	0.09	---
Total	101.2		

(a) Concentrations (wt.%) on an ash basis.

(b) Concentrations normalized to a closure of 100%.

(c) Concentrations renormalized to a SO3-free basis.

Comments:

TOTAL NUMBER OF POINTS = 250.0
SILICATE AND OTHER CRYSTALLINE PHASES

KERMANITE = .0
% GEHLENITE = .4
% ANORTHITE = 9.2
% ALBITE = .0
% NEPHELINE = .0
% LEUCITE = .0
% POTASSIUM FELDSPAR = .0
% PYROXENE = .0
% MULLITE = .0
% MERWINITE = .0
% CALCIUM SILICATE = .0
% (CA,MG,FE)SIO3 = .0
% DICALCIUM SILICATE = .0
% SPURRITE = .0
% NA2CASIO4 = .0
% HAUYNE = .0
% CALCIUM ALUMINATE = .0
% SPINEL = .0
% CALCIUM TITANATE = .0

OXIDE OR CARBONATE PHASES
% QUARTZ = 10.4
% IRON OXIDE = 6.0
% CALCIUM OXIDE = .0
% MAGNESIUM OXIDE = .0
% ANKERITE (CA,MG,FE)CO3 = .0
% ALUMINUM OXIDE = .0
% RUTILE = .0
% DOLOMITE = .0

SULFATE AND SULFIDE PHASES
% BARITE = .0
% ANHYDRITE = 1.2
% SULFATED DOLOMITE = .0
% SULFATED ANKERITE = .0
% SODIUM SULFATE = .0
% SODIUM CALCIUM SULFATE = .0
% FERRIC SULFATE = .0
% PYRRHOTITE = .0
% PYRITE = .0

UNCLASSIFIED AND DESIGNATED AMORPHOUS PHASES
% UNCLASSIFIED = 52.8
% PURE KAOLINITE (AMORP) = .4
% KAOLINITE DERIVED = 6.0
% ILLITE (AMORP) = 4.8
% MONTMORILLONITE (AMORP)= 8.8

THE FOLLOWING ARE ODD CRYSTALLINE PHASES
% APATITE = .0
CALCIUM DERIVED POINTS
% CALCIUM DERIVED = .0

CHEMICAL COMPOSITION WT %

	SIO2	AL2O3	FE2O3	TIO2	P2O5	CAO	MGO	NA2O	K2O	SO3	BAO	CR2O3	CLO
BULK	49.5	18.2	17.4	1.0	.4	6.0	.7	1.3	2.5	2.5	.0	.1	.5
AMORP.	48.7	21.2	15.6	1.2	.6	6.8	.9	1.6	3.3	.0	.0	.1	.0

ENERGY & ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
X-RAY POWDER DIFFRACTION REPORT

P.I.: Zygarlicke DATE: 7-25-91 ICC#: 53192991.XRD

SAMPLE DESCRIPTION: CCTI-Watson: Island Creek Baseline Coal XS-Air
Test 4 WW Panel 1 Inner

MAJOR PHASE(S):

NOMINAL COMPOSITION(S):

Hematite

Fe_2O_3

Quartz

SiO_2

Anhydrite

CaSO_4

Ferrite Spinel

$(\text{Mg}, \text{Fe})(\text{Fe}, \text{Al})_2\text{O}_4$

MINOR PHASE(S):

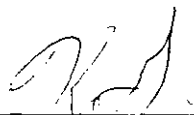
NOMINAL COMPOSITION(S):

Possible Plagioclase

$(\text{Ca}, \text{Na})(\text{Si}, \text{Al})_4\text{O}_8$

COMMENTS:

Analyzed by



ENERGY AND ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
EDXRF ANALYSIS REPORT

Date: 31-JUL-91

Inorganic Cost Center Number: 53192991

Coal Laboratory Number: 91-1214

Sample Description: Island Cr. BC T4 WW Panel 1 Inner X5- A

Sample Submitter: Zygarlicke

Analyst: Kevin Galbreath

Oxides (wt.%)	(a)	(b)	(c)
-----	----	----	----
SiO2	45.0	44.7	46.6
Al2O3	18.0	17.8	18.6
Fe2O3	24.4	24.2	25.2
MnO2	0.76	0.76	0.79
P2O5	0.29	0.29	0.31
CaO	3.37	3.35	3.49
MgO	1.01	1.00	1.04
Na2O	0.98	0.98	1.02
K2O	2.90	2.88	3.00
S O3	4.01	3.98	---
Total	100.6		

(a) Concentrations (wt.%) on an ash basis.

(b) Concentrations normalized to a closure of 100%.

(c) Concentrations renormalized to a SO3-free basis.

Comments:

TOTAL NUMBER OF POINTS = 250.0

SILICATE AND OTHER CRYSTALLINE PHASES

AKERMANITE	=	.0
GEHLENITE	=	.0
% ANORTHITE	=	.0
% ALBITE	=	.0
% NEPHELINE	=	.0
% LEUCITE	=	.0
% POTASSIUM FELDSPAR	=	.0
% PYROXENE	=	.0
% MULLITE	=	.0
% MERWINITE	=	.0
% CALCIUM SILICATE	=	.0
% (CA,MG,FE)SIO3	=	.0
% DICALCIUM SILICATE	=	.0
% SPURRITE	=	.0
% NA2CASIO4	=	.0
% HAUYNE	=	.0
% CALCIUM ALUMINATE	=	.0
% SPINEL	=	.0
% CALCIUM TITANATE	=	.0

OXIDE OR CARBONATE PHASES

% QUARTZ	=	4.4
% IRON OXIDE	=	7.2
% CALCIUM OXIDE	=	.4
% MAGNESIUM OXIDE	=	.0
% ANKERITE (CA,MG,FE)CO3	=	.0
% ALUMINUM OXIDE	=	1.2
% RUTILE	=	.0
% DOLOMITE	=	.0

SULFATE AND SULFIDE PHASES

% BARITE	=	.0
% ANHYDRITE	=	.0
% SULFATED DOLOMITE	=	.0
% SULFATED ANKERITE	=	.8
% SODIUM SULFATE	=	.0
% SODIUM CALCIUM SULFATE	=	.0
% FERRIC SULFATE	=	.4
% PYRRHOTITE	=	.0
% PYRITE	=	.0

UNCLASSIFIED AND DESIGNATED AMORPHOUS PHASES

% UNCLASSIFIED	=	74.4
% PURE KAOLINITE (AMORP)	=	.8
% KAOLINITE DERIVED	=	6.8
% ILLITE (AMORP)	=	2.0
% MONTMORILLONITE (AMORP)	=	1.2

THE FOLLOWING ARE ODD CRYSTALLINE PHASES

% APATITE	=	.0
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CALCIUM DERIVED POINTS

% CALCIUM DERIVED	=	.4
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CHEMICAL COMPOSITION WT %

	SIO2	AL2O3	FE2O3	TIO2	P2O5	CAO	MGO	NA2O	K2O	SO3	BAO	CR2O3	CLO
BULK	41.2	19.1	18.3	1.0	.2	3.7	.8	1.5	2.8	9.2	.0	.2	1.8
AMORP.	48.3	23.3	15.8	1.3	.3	4.1	1.1	1.9	3.6	.0	.0	.2	.0

ENERGY & ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
X-RAY POWDER DIFFRACTION REPORT

P.I.: Zygarlicke DATE: 7-25-91 ICC#: 53192995.XRD

SAMPLE DESCRIPTION: CCTI-Watson: Island Creek Baseline Coal XS-Air
Test 4 SH Probe 1A Inner

MAJOR PHASE(S):

Hematite

Anhydrite

NOMINAL COMPOSITION(S):

Fe_2O_3

CaSO_4

MINOR PHASE(S):

Quartz

Ferrite Spinel

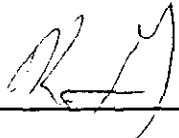
NOMINAL COMPOSITION(S):

SiO_2

$(\text{Mg}, \text{Fe}) (\text{Fe}, \text{Al})_2\text{O}_4$

COMMENTS:

Analyzed by



ENERGY AND ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
EDXRF ANALYSIS REPORT

Date: 30-JUL-91

Inorganic Cost Center Number: 53192995

Coal Laboratory Number: 91-1218

Sample Description: Island Cr. BC T4 SH Probe 1A Inner ~~VS-412~~

Sample Submitter: Zygarlicke

Analyst: Kevin Galbreath

Oxides (wt.%)	(a)	(b)	(c)
-----	----	----	----
SiO2	37.3	36.0	38.0
Al2O3	15.6	15.0	15.8
Fe2O3	35.5	34.3	36.1
TiO2	0.77	0.74	0.78
P2O5	0.53	0.51	0.53
CaO	5.46	5.28	5.56
MgO	0.88	0.85	0.90
Na2O	0.48	0.46	0.49
K2O	1.80	1.74	1.83
S O3	5.22	5.04	---
Total	103.6		

(a) Concentrations (wt.%) on an ash basis.

(b) Concentrations normalized to a closure of 100%.

(c) Concentrations renormalized to a SO3-free basis.

Comments:

TOTAL NUMBER OF POINTS = 250.0

SILICATE AND OTHER CRYSTALLINE PHASES

AKERMANITE	=	.0
GEHLENITE	=	.0
% ANORTHITE	=	.0
% ALBITE	=	.0
% NEPHELINE	=	.0
% LEUCITE	=	.0
% POTASSIUM FELDSPAR	=	.0
% PYROXENE	=	.0
% MULLITE	=	.0
% MERWINITE	=	.0
% CALCIUM SILICATE	=	.0
% (CA,MG,FE) SIO3	=	.0
% DICALCIUM SILICATE	=	.0
% SPURRITE	=	.0
% NA2CASIO4	=	.0
% HAUZYNE	=	.0
% CALCIUM ALUMINATE	=	.0
% SPINEL	=	.0
% CALCIUM TITANATE	=	.0

OXIDE OR CARBONATE PHASES

% QUARTZ	=	9.2
% IRON OXIDE	=	16.0
% CALCIUM OXIDE	=	.4
% MAGNESIUM OXIDE	=	.0
% ANKERITE (CA,MG,FE) CO3	=	.0
% ALUMINUM OXIDE	=	.0
% RUTILE	=	.0
% DOLOMITE	=	.0

SULFATE AND SULFIDE PHASES

% BARITE	=	.0
% ANHYDRITE	=	3.6
% SULFATED DOLOMITE	=	.0
% SULFATED ANKERITE	=	.0
% SODIUM SULFATE	=	.0
% SODIUM CALCIUM SULFATE	=	.0
% FERRIC SULFATE	=	.0
% PYRRHOTITE	=	.0
% PYRITE	=	.0

UNCLASSIFIED AND DESIGNATED AMORPHOUS PHASES

% UNCLASSIFIED	=	58.0
% PURE KAOLINITE (AMORP)	=	3.6
% KAOLINITE DERIVED	=	8.4
% ILLITE (AMORP)	=	.4
% MONTMORILLONITE (AMORP)	=	.0

THE FOLLOWING ARE ODD CRYSTALLINE PHASES

% APATITE	=	.4
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CALCIUM DERIVED POINTS

% CALCIUM DERIVED	=	.0
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CHEMICAL COMPOSITION WT %

	SIO2	AL2O3	FE2O3	TIO2	P2O5	CAO	MGO	NA2O	K2O	SO3	BAO	CR2O3	CLO
BULK	42.7	16.9	23.4	.9	.4	4.6	.7	1.2	2.1	6.3	.0	.1	.6
AMORP.	49.9	24.3	14.3	1.3	.4	4.2	.9	1.6	3.0	.0	.0	.1	.0

ENERGY & ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
X-RAY POWDER DIFFRACTION REPORT

P.I.: Zygarlicke DATE: 7-25-91 ICC#: 53192994.XRD

SAMPLE DESCRIPTION: CCTI-Watson: Island Creek Baseline Coal XS-Air
Test 4 SH Probe 1A Outer

MAJOR PHASE(S):

Hematite

NOMINAL COMPOSITION(S):

Fe_2O_3

MINOR PHASE(S):

Anhydrite

Quartz

Mullite

Possible Ferrite Spinel

NOMINAL COMPOSITION(S):

CaSO_4

SiO_2

$\text{Al}_6\text{Si}_4\text{O}_{13}$

$(\text{Mg}, \text{Fe}) (\text{Fe}, \text{Al})_2\text{O}_4$

COMMENTS:

Analyzed by



ENERGY AND ENVIRONMENTAL RESEARCH CENTER
UNIVERSITY OF NORTH DAKOTA
EDXRF ANALYSIS REPORT

Date: 30-JUL-91

Inorganic Cost Center Number: 53192994

Coal Laboratory Number: 91-1217

Sample Description: Island Cr. BC T4 SH Probe 1A Outer XRF

Sample Submitter: Zygarlicke

Analyst: Kevin Galbreath

Oxides (wt.%) -----	(a) ----	(b) ----	(c) ----
SiO2	46.2	44.1	44.9
Al2O3	19.3	18.4	18.7
Fe2O3	27.8	26.5	27.0
TiO2	0.76	0.73	0.74
P2O5	0.48	0.46	0.46
CaO	4.80	4.58	4.66
MgO	0.97	0.92	0.94
Na2O	0.70	0.67	0.68
K2O	2.01	1.92	1.95
S O3	1.84	1.76	---
Total	104.8		

(a) Concentrations (wt.%) on an ash basis.

(b) Concentrations normalized to a closure of 100%.

(c) Concentrations renormalized to a SO3-free basis.

Comments:

TOTAL NUMBER OF POINTS = 250.0

SILICATE AND OTHER CRYSTALLINE PHASES

% KERMANITE = .0
 % GEHLENITE = .0
 % ANORTHITE = .0
 % ALBITE = .0
 % NEPHELINE = .0
 % LEUCITE = .0
 % POTASSIUM FELDSPAR = .0
 % PYROXENE = .0
 % MULLITE = .0
 % MERWINITE = .0
 % CALCIUM SILICATE = .0
 % (CA,MG,FE) SIO3 = .0
 % DICALCIUM SILICATE = .0
 % SPURRITE = .0
 % NA2CASIO4 = .0
 % HAUYNE = .0
 % CALCIUM ALUMINATE = .0
 % SPINEL = .0
 % CALCIUM TITANATE = .0

OXIDE OR CARBONATE PHASES

% QUARTZ = 3.6
 % IRON OXIDE = 41.2
 % CALCIUM OXIDE = .0
 % MAGNESIUM OXIDE = .0
 % ANKERITE (CA,MG,FE) CO3 = 1.2
 % ALUMINUM OXIDE = .0
 % RUTILE = .0
 % DOLOMITE = .0

SULFATE AND SULFIDE PHASES

% BARITE = .0
 % ANHYDRITE = 11.2
 % SULFATED DOLOMITE = .0
 % SULFATED ANKERITE = .4
 % SODIUM SULFATE = .0
 % SODIUM CALCIUM SULFATE = .0
 % FERRIC SULFATE = .0
 % PYRRHOTITE = .0
 % PYRITE = .0

UNCLASSIFIED AND DESIGNATED AMORPHOUS PHASES

% UNCLASSIFIED = 37.6
 % PURE KAOLINITE (AMORP) = .4
 % KAOLINITE DERIVED = 2.4
 % ILLITE (AMORP) = .4
 % MONTMORILLONITE (AMORP) = .4

THE FOLLOWING ARE ODD CRYSTALLINE PHASES

% APATITE = 1.2

CALCIUM DERIVED POINTS

% CALCIUM DERIVED = .0

CHEMICAL COMPOSITION WT %

	SIO2	AL2O3	FE2O3	TIO2	P2O5	CAO	MGO	NA2O	K2O	SO3	BAO	CR2O3	CLO
BULK	20.7	8.6	48.7	.7	1.1	8.8	.5	.7	.8	9.2	.0	.1	.1
AMORP.	34.8	16.9	31.5	1.3	.7	10.8	1.1	1.1	1.7	.0	.0	.1	.0

APPENDIX D

CE PILOT-SCALE (FPTF) DATA

WATSON ISLAND CREEK BASELINE TEST 1

COMBUSTION DATA

FUEL FEED RATE (LB/HR)	276.14
ADDITIVE FEED/RATE (LB/HR)	.00
FUEL HHV (BTU/LB)	12837.00
TOTAL HEAT INPUT (MBTU/HR)	4.41
PRIMARY AIR FLOW (LB/HR)	324.45
PRIMARY AIR TEMP. (F)	77.02
SECONDARY AIR FLOW (LB/HR)	2865.19
SECONDARY AIR TEMP. (F)	1238.84
TRANSPORT AIR FLOW (LB/HR)	.00
OXYGEN IN FLUE GAS (PCT)	5.11
PERCENT EXCESS AIR	19.26
LOWER FURNACE PEAK FLAME TEMP. (F)	2904.60
LOWER FURNACE RESIDENCE TIME (SEC)	1.24

WATERWALL TEST PANELS

PANEL P1 SURFACE TEMP. (F)	707.52
PANEL P2 SURFACE TEMP. (F)	675.05
PANEL P3 SURFACE TEMP. (F)	703.82
PANEL P4 SURFACE TEMP. (F)	702.72

SUPERHEATER PROBES

DUCT 1 GAS TEMPERATURE (F)	2212.52
DUCT 2 GAS TEMPERATURE (F)	2133.13
DUCT 3 GAS TEMPERATURE (F)	1958.51
DUCT 4 GAS TEMPERATURE (F)	1821.90
EROSION DUCT GAS TEMP. (F)	1300.00
DUCT 1 GAS VELOCITY (FT/SEC)	64.81
DUCT 2 GAS VELOCITY (FT/SEC)	62.89
DUCT 3 GAS VELOCITY (FT/SEC)	58.65
DUCT 4 GAS VELOCITY (FT/SEC)	55.34
ER.DUCT GAS VEL.[1] (FT/SEC)	199.19
ER.DUCT GAS VEL.[2] (FT/SEC)	221.83

ASH

INPUT (LB/HR)	19.33
DUST LOADING (LB/HR)	10.70
CARBON CONVERSION (PCT)	100.000
CARBON HEAT LOSS (PCT)	.000

TOTAL HEAT OUTPUT (MBTU/HR)	4.34
HEAT UNACCOUNTED FOR (PCT)	1.51

RESIDENCE TIME ALONG GAS STREAM

LOCATION	TEMP. (F)	TIME, SEC.
SUCTION PORT L1	2905.	.282
SUCTION PORT L2	2812.	.403
SUCTION PORT L3	2718.	.519
SUCTION PORT L4	2599.	.763
SUCTION PORT L5	2404.	1.240
S.H DUCT 1A	2213.	1.465
S.H DUCT 2C	2133.	1.503
S.H DUCT 3E	1959.	1.540
S.H DUCT 4G	1822.	1.606
DUST LOADING PORT	1300.	1.857

WATSON: ISLAND CREEK BASELINE TEST 2

COMBUSTION DATA

FUEL FEED RATE (LB/HR)	288.71
ADDITIVE FEED/RATE (LB/HR)	.00
FUEL HHV (BTU/LB)	12837.00
TOTAL HEAT INPUT (MBTU/HR)	4.66
PRIMARY AIR FLOW (LB/HR)	320.06
PRIMARY AIR TEMP. (F)	84.32
SECONDARY AIR FLOW (LB/HR)	3076.43
SECONDARY AIR TEMP. (F)	1280.81
TRANSPORT AIR FLOW (LB/HR)	.00
OXYGEN IN FLUE GAS (PCT)	5.27
PERCENT EXCESS AIR	21.47
LOWER FURNACE PEAK FLAME TEMP. (F)	2927.29
LOWER FURNACE RESIDENCE TIME (SEC)	1.15

WATERWALL TEST PANELS

PANEL P1 SURFACE TEMP. (F)	706.36
PANEL P2 SURFACE TEMP. (F)	648.61
PANEL P3 SURFACE TEMP. (F)	704.74
PANEL P4 SURFACE TEMP. (F)	702.92

SUPERHEATER PROBES

DUCT 1 GAS TEMPERATURE (F)	2324.32
DUCT 2 GAS TEMPERATURE (F)	2198.05
DUCT 3 GAS TEMPERATURE (F)	2055.16
DUCT 4 GAS TEMPERATURE (F)	1852.32
EROSION DUCT GAS TEMP. (F)	1320.00
DUCT 1 GAS VELOCITY (FT/SEC)	71.85
DUCT 2 GAS VELOCITY (FT/SEC)	68.59
DUCT 3 GAS VELOCITY (FT/SEC)	64.90
DUCT 4 GAS VELOCITY (FT/SEC)	59.67
ER.DUCT GAS VEL.[1] (FT/SEC)	214.35
ER.DUCT GAS VEL.[2] (FT/SEC)	236.98

ASH

INPUT (LB/HR)	20.21
DUST LOADING (LB/HR)	10.00
CARBON CONVERSION (PCT)	100.000
CARBON HEAT LOSS (PCT)	.000

METHOD 1-----

FLUE GAS FLOW RATE (LB/HR)	3665.652	
COMPOSITION (MOLES/HR), (PERCENT)		
OXYGEN	4.490	3.63
CARBON DIOXIDE	17.106	13.83
WATER	10.030	8.11
SULFUR DIOXIDE	.271	.22
NITROGEN	91.837	74.22

METHOD 2-----

FLUE GAS FLOW RATE (LB/HR)	4039.750	
COMPOSITION (MOLES/HR), PERCENT		
OXYGEN	7.209	5.27
CARBON DIOXIDE	17.106	12.51
WATER	10.275	7.51
SULFUR DIOXIDE	.271	.20
NITROGEN	101.932	74.52

	KBTU/HR	PCT
HEAT OUT		
HEAT LOSS FROM REFRACTORY	230.611	4.95
HEAT LOSS FROM PANELS	466.316	10.00
HEAT LOSS FROM WATER COOLED FRAME	168.412	3.61
HEAT LOSS FROM FLY ASH	5.600	.12
HEAT LOSS FROM UNBURNT CARBON	.000	.00
HEAT LOSS FROM ROOF	68.116	1.46
HEAT LOSS FROM S.H. TRANSITION	153.382	3.29
HEAT LOSS FROM S.H. FRAME	130.620	2.80
HEAT LOSS FROM S.H. DUCT	148.213	3.18
HEAT LOSS FROM OBS. PORT	56.868	1.22
HEAT LOSS FROM BURNER	275.136	5.90
HEAT LOSS FROM FURNACE BOTTOM LEFT	97.288	2.09
HEAT LOSS FROM FURNACE BOTTOM RIGHT	85.089	1.82
HEAT LOSS FROM FLUE GAS, [METHOD 1]	2469.152	52.95
HEAT LOSS FROM FLUE GAS, [METHOD 2]	2727.202	58.48

METHOD 1-----TOTAL MATERIAL INPUT (LB/HR)	3685.21
TOTAL MATERIAL OUTPUT (LB/HR)	3684.65
MATERIAL UNACCOUNTED FOR	.02
TOTAL HEAT INPUT (MBTU/HR)	4.66
TOTAL HEAT OUTPUT (MBTU/HR)	4.39
HEAT UNACCOUNTED FOR (PCT)	5.82

METHOD 2-----TOTAL MATERIAL INPUT (LB/HR)	4059.96
TOTAL MATERIAL OUTPUT (LB/HR)	4058.75
MATERIAL UNACCOUNTED FOR (PCT)	.03

TOTAL HEAT OUTPUT (MBTU/HR)	4.65
HEAT UNACCOUNTED FOR (PCT)	.28

RESIDENCE TIME ALONG GAS STREAM

LOCATION	TEMP. (F)	TIME, SEC.
SUCTION PORT L1	2946.	.263
SUCTION PORT L2	2826.	.375
SUCTION PORT L3	2720.	.484
SUCTION PORT L4	2653.	.712
SUCTION PORT L5	2500.	1.149
S.H DUCT 1A	2324.	1.353
S.H DUCT 2C	2198.	1.387
S.H DUCT 3E	2055.	1.421
S.H DUCT 4G	1852.	1.482
DUST LOADING PORT	1320.	1.717

WATSON: ISLAND CREEK BASELINE TEST 3

COMBUSTION DATA

FUEL FEED RATE (LB/HR)	267.07
ADDITIVE FEED/RATE (LB/HR)	.00
FUEL HHV (BTU/LB)	12837.00
TOTAL HEAT INPUT (MBTU/HR)	4.26
PRIMARY AIR FLOW (LB/HR)	324.84
PRIMARY AIR TEMP. (F)	77.62
SECONDARY AIR FLOW (LB/HR)	2783.58
SECONDARY AIR TEMP. (F)	1219.88
TRANSPORT AIR FLOW (LB/HR)	.00
OXYGEN IN FLUE GAS (PCT)	5.30
PERCENT EXCESS AIR	20.18
LOWER FURNACE PEAK FLAME TEMP. (F)	2870.00
LOWER FURNACE RESIDENCE TIME (SEC)	1.32

WATERWALL TEST PANELS

PANEL P1 SURFACE TEMP. (F)	707.01
PANEL P2 SURFACE TEMP. (F)	674.42
PANEL P3 SURFACE TEMP. (F)	703.52
PANEL P4 SURFACE TEMP. (F)	702.83

SUPERHEATER PROBES

DUCT 1 GAS TEMPERATURE (F)	2147.00
DUCT 2 GAS TEMPERATURE (F)	2040.00
DUCT 3 GAS TEMPERATURE (F)	1907.00
DUCT 4 GAS TEMPERATURE (F)	1708.00
EROSION DUCT GAS TEMP. (F)	1275.00
DUCT 1 GAS VELOCITY (FT/SEC)	61.60
DUCT 2 GAS VELOCITY (FT/SEC)	59.07
DUCT 3 GAS VELOCITY (FT/SEC)	55.92
DUCT 4 GAS VELOCITY (FT/SEC)	51.22
ER.DUCT GAS VEL.[1] (FT/SEC)	191.30
ER.DUCT GAS VEL.[2] (FT/SEC)	214.08

ASH

INPUT (LB/HR)	18.69
DUST LOADING (LB/HR)	10.00
CARBON CONVERSION (PCT)	100.000
CARBON HEAT LOSS (PCT)	.000

METHOD 1-----

FLUE GAS FLOW RATE (LB/HR)	3357.396	
COMPOSITION (MOLES/HR), (PERCENT)		
OXYGEN	3.911	3.45
CARBON DIOXIDE	15.824	13.97
WATER	9.256	8.17
SULFUR DIOXIDE	.250	.22
NITROGEN	84.050	74.19

METHOD 2-----

FLUE GAS FLOW RATE (LB/HR)	3743.843	
COMPOSITION (MOLES/HR), PERCENT		
OXYGEN	6.719	5.30
CARBON DIOXIDE	15.824	12.48
WATER	9.509	7.50
SULFUR DIOXIDE	.250	.20
NITROGEN	94.478	74.52

HEAT OUT

	KBTU/HR	PCT
HEAT LOSS FROM REFRACTORY	230.047	5.41
HEAT LOSS FROM PANELS	446.292	10.49
HEAT LOSS FROM WATER COOLED FRAME	148.436	3.49
HEAT LOSS FROM FLY ASH	5.173	.12
HEAT LOSS FROM UNBURNT CARBON	.000	.00
HEAT LOSS FROM ROOF	60.038	1.41
HEAT LOSS FROM S.H. TRANSITION	157.762	3.71
HEAT LOSS FROM S.H. FRAME	112.686	2.65
HEAT LOSS FROM S.H. DUCT	145.083	3.41
HEAT LOSS FROM OBS. PORT	59.382	1.40
HEAT LOSS FROM BURNER	237.717	5.59
HEAT LOSS FROM FURNACE BOTTOM LEFT	85.196	2.00
HEAT LOSS FROM FURNACE BOTTOM RIGHT	85.196	2.00
HEAT LOSS FROM FLUE GAS, [METHOD 1]	2059.448	48.40
HEAT LOSS FROM FLUE GAS, [METHOD 2]	2299.951	54.05

METHOD 1-----TOTAL MATERIAL INPUT (LB/HR)	3375.49
TOTAL MATERIAL OUTPUT (LB/HR)	3375.40
MATERIAL UNACCOUNTED FOR	.00
TOTAL HEAT INPUT (MBTU/HR)	4.26
TOTAL HEAT OUTPUT (MBTU/HR)	3.86
HEAT UNACCOUNTED FOR (PCT)	9.25

METHOD 2-----TOTAL MATERIAL INPUT (LB/HR)	3762.54
TOTAL MATERIAL OUTPUT (LB/HR)	3761.84
MATERIAL UNACCOUNTED FOR (PCT)	.02

TOTAL HEAT OUTPUT (MBTU/HR)	4.10
HEAT UNACCOUNTED FOR (PCT)	3.59

RESIDENCE TIME ALONG GAS STREAM

LOCATION	TEMP. (F)	TIME, SEC.
SUCTION PORT L1	2870.	.293
SUCTION PORT L2	2771.	.418
SUCTION PORT L3	2280.	.547
SUCTION PORT L4	2567.	.818
SUCTION PORT L5	2398.	1.310
S.H DUCT 1A	2147.	1.545
S.H DUCT 2C	2040.	1.585
S.H DUCT 3E	1907.	1.623
S.H DUCT 4G	1708.	1.693
DUST LOADING PORT	1275.	1.959

WATSON: ISLAND CREEK BASELINE TEST 4

COMBUSTION DATA

FUEL FEED RATE (LB/HR)	275.44
ADDITIVE FEED/RATE (LB/HR)	.00
FUEL HHV (BTU/LB)	12837.00
TOTAL HEAT INPUT (MBTU/HR)	4.27
PRIMARY AIR FLOW (LB/HR)	321.07
PRIMARY AIR TEMP. (F)	80.51
SECONDARY AIR FLOW (LB/HR)	2895.65
SECONDARY AIR TEMP. (F)	1056.77
TRANSPORT AIR FLOW (LB/HR)	.00
OXYGEN IN FLUE GAS (PCT)	5.31
PERCENT EXCESS AIR	20.58
LOWER FURNACE PEAK FLAME TEMP. (F)	2969.34
LOWER FURNACE RESIDENCE TIME (SEC)	1.22

WATERWALL TEST PANELS

PANEL P1 SURFACE TEMP. (F)	706.36
PANEL P2 SURFACE TEMP. (F)	659.98
PANEL P3 SURFACE TEMP. (F)	704.63
PANEL P4 SURFACE TEMP. (F)	702.60

SUPERHEATER PROBES

DUCT 1 GAS TEMPERATURE (F)	2195.54
DUCT 2 GAS TEMPERATURE (F)	2093.49
DUCT 3 GAS TEMPERATURE (F)	1973.47
DUCT 4 GAS TEMPERATURE (F)	1795.61
EROSION DUCT GAS TEMP. (F)	1300.00
DUCT 1 GAS VELOCITY (FT/SEC)	64.92
DUCT 2 GAS VELOCITY (FT/SEC)	62.42
DUCT 3 GAS VELOCITY (FT/SEC)	59.49
DUCT 4 GAS VELOCITY (FT/SEC)	55.14
ER.DUCT GAS VEL.[1] (FT/SEC)	200.79
ER.DUCT GAS VEL.[2] (FT/SEC)	224.12

ASH

INPUT (LB/HR)	19.28
DUST LOADING (LB/HR)	10.00
CARBON CONVERSION (PCT)	100.000
CARBON HEAT LOSS (PCT)	.000

METHOD 1-----

FLUE GAS FLOW RATE (LB/HR)	3473.506	
COMPOSITION (MOLES/HR), (PERCENT)		
OXYGEN	4.112	3.51
CARBON DIOXIDE	16.320	13.92
WATER	9.553	8.15
SULFUR DIOXIDE	.258	.22
NITROGEN	86.978	74.20

METHOD 2-----

FLUE GAS FLOW RATE (LB/HR)	3863.657	
COMPOSITION (MOLES/HR), PERCENT		
OXYGEN	6.948	5.31
CARBON DIOXIDE	16.320	12.47
WATER	9.809	7.50
SULFUR DIOXIDE	.258	.20
NITROGEN	97.506	74.52

HEAT OUT

	KBTU/HR	PCT
HEAT LOSS FROM REFRACTORY	225.158	5.27
HEAT LOSS FROM PANELS	426.418	9.98
HEAT LOSS FROM WATER COOLED FRAME	147.376	3.45
HEAT LOSS FROM FLY ASH	5.288	.12
HEAT LOSS FROM UNBURNT CARBON	.000	.00
HEAT LOSS FROM ROOF	58.782	1.38
HEAT LOSS FROM S.H. TRANSITION	142.658	3.34
HEAT LOSS FROM S.H. FRAME	99.026	2.32
HEAT LOSS FROM S.H. DUCT	147.745	3.46
HEAT LOSS FROM OBS. PORT	64.198	1.50
HEAT LOSS FROM BURNER	204.450	4.79
HEAT LOSS FROM FURNACE BOTTOM LEFT	72.931	1.71
HEAT LOSS FROM FURNACE BOTTOM RIGHT	63.167	1.48
HEAT LOSS FROM FLUE GAS, [METHOD 1]	2186.764	51.20
HEAT LOSS FROM FLUE GAS, [METHOD 2]	2436.573	57.05

METHOD 1-----TOTAL MATERIAL INPUT (LB/HR)	3492.17
TOTAL MATERIAL OUTPUT (LB/HR)	3491.51
MATERIAL UNACCOUNTED FOR	.02
TOTAL HEAT INPUT (MBTU/HR)	4.27
TOTAL HEAT OUTPUT (MBTU/HR)	3.88
HEAT UNACCOUNTED FOR (PCT)	9.26

METHOD 2-----TOTAL MATERIAL INPUT (LB/HR)	3882.94
TOTAL MATERIAL OUTPUT (LB/HR)	3881.66
MATERIAL UNACCOUNTED FOR (PCT)	.03

TOTAL HEAT OUTPUT (MBTU/HR)	4.13
HEAT UNACCOUNTED FOR (PCT)	3.41

RESIDENCE TIME ALONG GAS STREAM

LOCATION	TEMP. (F)	TIME, SEC.
SUCTION PORT L1	2969.	.275
SUCTION PORT L2	2829.	.393
SUCTION PORT L3	2690.	.508
SUCTION PORT L4	2645.	.750
SUCTION PORT L5	2472.	1.214
S.H DUCT 1A	2196.	1.435
S.H DUCT 2C	2093.	1.473
S.H DUCT 3E	1973.	1.510
S.H DUCT 4G	1796.	1.575
DUST LOADING PORT	1300.	1.826

WATSON : ISLAND CREEK COAL EXCESS AIR TEST 1

COMBUSTION DATA

FUEL FEED RATE (LB/HR)	281.00
ADDITIVE FEED/RATE (LB/HR)	.00
FUEL HHV (BTU/LB)	12837.00
TOTAL HEAT INPUT (MBTU/HR)	4.35
PRIMARY AIR FLOW (LB/HR)	319.61
PRIMARY AIR TEMP. (F)	87.78
SECONDARY AIR FLOW (LB/HR)	2613.94
SECONDARY AIR TEMP. (F)	1176.19
TRANSPORT AIR FLOW (LB/HR)	.00
OXYGEN IN FLUE GAS (PCT)	3.00
PERCENT EXCESS AIR	7.79
LOWER FURNACE PEAK FLAME TEMP. (F)	2916.88
LOWER FURNACE RESIDENCE TIME (SEC)	1.35

WATERWALL TEST PANELS

PANEL P1 SURFACE TEMP. (F)	706.98
PANEL P2 SURFACE TEMP. (F)	699.53
PANEL P3 SURFACE TEMP. (F)	705.92
PANEL P4 SURFACE TEMP. (F)	702.29

SUPERHEATER PROBES

DUCT 1 GAS TEMPERATURE (F)	2235.47
DUCT 2 GAS TEMPERATURE (F)	2082.71
DUCT 3 GAS TEMPERATURE (F)	1968.04
DUCT 4 GAS TEMPERATURE (F)	1804.54
EROSION DUCT GAS TEMP. (F)	1245.00
DUCT 1 GAS VELOCITY (FT/SEC)	60.39
DUCT 2 GAS VELOCITY (FT/SEC)	56.97
DUCT 3 GAS VELOCITY (FT/SEC)	54.40
DUCT 4 GAS VELOCITY (FT/SEC)	50.74
ER.DUCT GAS VEL.[1] (FT/SEC)	178.27
ER.DUCT GAS VEL.[2] (FT/SEC)	192.78

ASH

INPUT (LB/HR)	19.67
DUST LOADING (LB/HR)	10.00
CARBON CONVERSION (PCT)	100.000
CARBON HEAT LOSS (PCT)	.000

METHOD 1-----

FLUE GAS FLOW RATE (LB/HR)	3195.453	
COMPOSITION (MOLES/HR), (PERCENT)		
OXYGEN	1.664	1.55
CARBON DIOXIDE	16.649	15.50
WATER	9.517	8.86
SULFUR DIOXIDE	.263	.25
NITROGEN	79.338	73.85

METHOD 2-----

FLUE GAS FLOW RATE (LB/HR)	3446.007	
COMPOSITION (MOLES/HR), PERCENT		
OXYGEN	3.485	3.00
CARBON DIOXIDE	16.649	14.33
WATER	9.681	8.33
SULFUR DIOXIDE	.263	.23
NITROGEN	86.099	74.11

HEAT OUT	KBTU/HR	PCT
HEAT LOSS FROM REFRACTORY	222.512	5.12
HEAT LOSS FROM PANELS	508.137	11.69
HEAT LOSS FROM WATER COOLED FRAME	195.442	4.50
HEAT LOSS FROM FLY ASH	5.369	.12
HEAT LOSS FROM UNBURNT CARBON	.000	.00
HEAT LOSS FROM ROOF	64.952	1.49
HEAT LOSS FROM S.H. TRANSITION	123.580	2.84
HEAT LOSS FROM S.H. FRAME	93.914	2.16
HEAT LOSS FROM S.H. DUCT	133.923	3.08
HEAT LOSS FROM OBS. PORT	82.875	1.91
HEAT LOSS FROM BURNER	286.985	6.60
HEAT LOSS FROM FURNACE BOTTOM LEFT	95.220	2.19
HEAT LOSS FROM FURNACE BOTTOM RIGHT	95.220	2.19
HEAT LOSS FROM FLUE GAS, [METHOD 1]	2046.395	47.08
HEAT LOSS FROM FLUE GAS, [METHOD 2]	2210.277	50.85

METHOD 1-----TOTAL MATERIAL INPUT (LB/HR)	3214.56
TOTAL MATERIAL OUTPUT (LB/HR)	3213.95
MATERIAL UNACCOUNTED FOR	.02
TOTAL HEAT INPUT (MBTU/HR)	4.35
TOTAL HEAT OUTPUT (MBTU/HR)	4.00
HEAT UNACCOUNTED FOR (PCT)	8.03

METHOD 2-----TOTAL MATERIAL INPUT (LB/HR)	3465.68
TOTAL MATERIAL OUTPUT (LB/HR)	3464.51
MATERIAL UNACCOUNTED FOR (PCT)	.03

TOTAL HEAT OUTPUT (MBTU/HR)	4.16
HEAT UNACCOUNTED FOR (PCT)	4.26

RESIDENCE TIME ALONG GAS STREAM

LOCATION	TEMP. (F)	TIME, SEC.
SUCTION PORT L1	2917.	.304
SUCTION PORT L2	2797.	.435
SUCTION PORT L3	2695.	.562
SUCTION PORT L4	2627.	.826
SUCTION PORT L5	2379.	1.342
S.H DUCT 1A	2235.	1.585
S.H DUCT 2C	2083.	1.627
S.H DUCT 3E	1968.	1.669
S.H DUCT 4G	1805.	1.742
DUST LOADING PORT	1245.	2.028

WATSON: ISLAND CREEK COAL - EXCESS AIR TEST 2

COMBUSTION DATA

FUEL FEED RATE (LB/HR)	264.64
ADDITIVE FEED/RATE (LB/HR)	.00
FUEL HHV (BTU/LB)	12852.00
TOTAL HEAT INPUT (MBTU/HR)	4.05
PRIMARY AIR FLOW (LB/HR)	319.90
PRIMARY AIR TEMP. (F)	87.98
SECONDARY AIR FLOW (LB/HR)	2478.11
SECONDARY AIR TEMP. (F)	1089.92
TRANSPORT AIR FLOW (LB/HR)	.00
OXYGEN IN FLUE GAS (PCT)	3.60
PERCENT EXCESS AIR	9.17
LOWER FURNACE PEAK FLAME TEMP. (F)	2888.00
LOWER FURNACE RESIDENCE TIME (SEC)	1.42

WATERWALL TEST PANELS

PANEL P1 SURFACE TEMP. (F)	706.85
PANEL P2 SURFACE TEMP. (F)	683.28
PANEL P3 SURFACE TEMP. (F)	705.28
PANEL P4 SURFACE TEMP. (F)	702.11

SUPERHEATER PROBES

DUCT 1 GAS TEMPERATURE (F)	2170.52
DUCT 2 GAS TEMPERATURE (F)	2129.81
DUCT 3 GAS TEMPERATURE (F)	1987.17
DUCT 4 GAS TEMPERATURE (F)	1746.58
EROSION DUCT GAS TEMP. (F)	1200.00
DUCT 1 GAS VELOCITY (FT/SEC)	56.18
DUCT 2 GAS VELOCITY (FT/SEC)	55.31
DUCT 3 GAS VELOCITY (FT/SEC)	52.27
DUCT 4 GAS VELOCITY (FT/SEC)	47.13
ER.DUCT GAS VEL.[1] (FT/SEC)	165.45
ER.DUCT GAS VEL.[2] (FT/SEC)	182.92

ASH

INPUT (LB/HR)	18.52
DUST LOADING (LB/HR)	9.75
CARBON CONVERSION (PCT)	100.000
CARBON HEAT LOSS (PCT)	.000

METHOD 1-----

FLUE GAS FLOW RATE (LB/HR)	3044.665	
COMPOSITION (MOLES/HR), (PERCENT)		
OXYGEN	1.824	1.78
CARBON DIOXIDE	15.680	15.31
WATER	8.986	8.77
SULFUR DIOXIDE	.248	.24
NITROGEN	75.670	73.89

METHOD 2-----

FLUE GAS FLOW RATE (LB/HR)	3354.525	
COMPOSITION (MOLES/HR), PERCENT		
OXYGEN	4.076	3.60
CARBON DIOXIDE	15.680	13.85
WATER	9.189	8.12
SULFUR DIOXIDE	.248	.22
NITROGEN	84.032	74.22

HEAT OUT

	KBTU/HR	PCT
HEAT LOSS FROM REFRACTORY	232.963	5.76
HEAT LOSS FROM PANELS	481.235	11.89
HEAT LOSS FROM WATER COOLED FRAME	178.510	4.41
HEAT LOSS FROM FLY ASH	5.076	.13
HEAT LOSS FROM UNBURNT CARBON	.000	.00
HEAT LOSS FROM ROOF	59.411	1.47
HEAT LOSS FROM S.H. TRANSITION	128.711	3.18
HEAT LOSS FROM S.H. FRAME	110.961	2.74
HEAT LOSS FROM S.H. DUCT	127.471	3.15
HEAT LOSS FROM OBS. PORT	70.133	1.73
HEAT LOSS FROM BURNER	244.635	6.05
HEAT LOSS FROM FURNACE BOTTOM LEFT	80.359	1.99
HEAT LOSS FROM FURNACE BOTTOM RIGHT	81.402	2.01
HEAT LOSS FROM FLUE GAS, [METHOD 1]	1882.407	46.52
HEAT LOSS FROM FLUE GAS, [METHOD 2]	2077.294	51.33

METHOD 1-----TOTAL MATERIAL INPUT (LB/HR)	3062.65
TOTAL MATERIAL OUTPUT (LB/HR)	3062.42
MATERIAL UNACCOUNTED FOR	.01
TOTAL HEAT INPUT (MBTU/HR)	4.05
TOTAL HEAT OUTPUT (MBTU/HR)	3.72
HEAT UNACCOUNTED FOR (PCT)	8.00

METHOD 2-----TOTAL MATERIAL INPUT (LB/HR)	3373.05
TOTAL MATERIAL OUTPUT (LB/HR)	3372.27
MATERIAL UNACCOUNTED FOR (PCT)	.02

TOTAL HEAT OUTPUT (MBTU/HR)	3.92
HEAT UNACCOUNTED FOR (PCT)	3.18

RESIDENCE TIME ALONG GAS STREAM

LOCATION	TEMP. (F)	TIME, SEC.
SUCTION PORT L1	2888.	.322
SUCTION PORT L2	2785.	.460
SUCTION PORT L3	2694.	.593
SUCTION PORT L4	2614.	.871
SUCTION PORT L5	2414.	1.410
S.H DUCT 1A	2171.	1.667
S.H DUCT 2C	2130.	1.711
S.H DUCT 3E	1987.	1.753
S.H DUCT 4G	1747.	1.829
DUST LOADING PORT	1200.	2.130

WATSON : ISLAND CREEK COAL - EXCESS AIR TEST 3

COMBUSTION DATA

FUEL FEED RATE (LB/HR)	249.99
ADDITIVE FEED/RATE (LB/HR)	.00
FUEL HHV (BTU/LB)	12837.00
TOTAL HEAT INPUT (MBTU/HR)	3.75
PRIMARY AIR FLOW (LB/HR)	323.65
PRIMARY AIR TEMP. (F)	84.02
SECONDARY AIR FLOW (LB/HR)	2290.07
SECONDARY AIR TEMP. (F)	997.59
TRANSPORT AIR FLOW (LB/HR)	.00
OXYGEN IN FLUE GAS (PCT)	3.65
PERCENT EXCESS AIR	7.95
LOWER FURNACE PEAK FLAME TEMP. (F)	2833.00
LOWER FURNACE RESIDENCE TIME (SEC)	1.54

WATERWALL TEST PANELS

PANEL P1 SURFACE TEMP. (F)	706.76
PANEL P2 SURFACE TEMP. (F)	670.93
PANEL P3 SURFACE TEMP. (F)	703.98
PANEL P4 SURFACE TEMP. (F)	702.13

SUPERHEATER PROBES

DUCT 1 GAS TEMPERATURE (F)	2100.00
DUCT 2 GAS TEMPERATURE (F)	1977.00
DUCT 3 GAS TEMPERATURE (F)	1829.00
DUCT 4 GAS TEMPERATURE (F)	1674.00
EROSION DUCT GAS TEMP. (F)	1180.00
DUCT 1 GAS VELOCITY (FT/SEC)	51.10
DUCT 2 GAS VELOCITY (FT/SEC)	48.64
DUCT 3 GAS VELOCITY (FT/SEC)	45.69
DUCT 4 GAS VELOCITY (FT/SEC)	42.60
ER.DUCT GAS VEL.[1] (FT/SEC)	152.77
ER.DUCT GAS VEL.[2] (FT/SEC)	171.22

ASH

INPUT (LB/HR)	17.50
DUST LOADING (LB/HR)	8.50
CARBON CONVERSION (PCT)	100.000
CARBON HEAT LOSS (PCT)	.000

METHOD 1-----

FLUE GAS FLOW RATE (LB/HR)	2846.710	
COMPOSITION (MOLES/HR), (PERCENT)		
OXYGEN	1.509	1.58
CARBON DIOXIDE	14.812	15.48
WATER	8.469	8.85
SULFUR DIOXIDE	.234	.24
NITROGEN	70.688	73.85

METHOD 2-----

FLUE GAS FLOW RATE (LB/HR)	3177.775	
COMPOSITION (MOLES/HR), PERCENT		
OXYGEN	3.915	3.65
CARBON DIOXIDE	14.812	13.81
WATER	8.687	8.10
SULFUR DIOXIDE	.234	.22
NITROGEN	79.622	74.23

HEAT OUT

	KBTU/HR	PCT
HEAT LOSS FROM REFRACTORY	228.608	6.09
HEAT LOSS FROM PANELS	472.674	12.59
HEAT LOSS FROM WATER COOLED FRAME	168.143	4.48
HEAT LOSS FROM FLY ASH	4.284	.11
HEAT LOSS FROM UNBURNT CARBON	.000	.00
HEAT LOSS FROM ROOF	53.762	1.43
HEAT LOSS FROM S.H. TRANSITION	117.832	3.14
HEAT LOSS FROM S.H. FRAME	94.006	2.50
HEAT LOSS FROM S.H. DUCT	112.150	2.99
HEAT LOSS FROM OBS. PORT	72.498	1.93
HEAT LOSS FROM BURNER	212.359	5.66
HEAT LOSS FROM FURNACE BOTTOM LEFT	68.796	1.83
HEAT LOSS FROM FURNACE BOTTOM RIGHT	68.796	1.83
HEAT LOSS FROM FLUE GAS, [METHOD 1]	1693.837	45.13
HEAT LOSS FROM FLUE GAS, [METHOD 2]	1893.486	50.45

METHOD 1-----TOTAL MATERIAL INPUT (LB/HR)	2863.71
TOTAL MATERIAL OUTPUT (LB/HR)	2862.71
MATERIAL UNACCOUNTED FOR	.03
TOTAL HEAT INPUT (MBTU/HR)	3.75
TOTAL HEAT OUTPUT (MBTU/HR)	3.41
HEAT UNACCOUNTED FOR (PCT)	9.12

METHOD 2-----TOTAL MATERIAL INPUT (LB/HR)	3195.28
TOTAL MATERIAL OUTPUT (LB/HR)	3193.78
MATERIAL UNACCOUNTED FOR (PCT)	.05

TOTAL HEAT OUTPUT (MBTU/HR)	3.61
HEAT UNACCOUNTED FOR (PCT)	3.80

RESIDENCE TIME ALONG GAS STREAM

LOCATION	TEMP. (F)	TIME, SEC.
SUCTION PORT L1	2833.	.350
SUCTION PORT L2	2724.	.500
SUCTION PORT L3	2658.	.645
SUCTION PORT L4	2582.	.946
SUCTION PORT L5	2377.	1.529
S.H DUCT 1A	2100.	1.810
S.H DUCT 2C	1977.	1.858
S.H DUCT 3E	1829.	1.905
S.H DUCT 4G	1674.	1.989
DUST LOADING PORT	1180.	2.314

WATSON : ISLAND CREEK COAL - EXCESS AIR TEST 4

COMBUSTION DATA

FUEL FEED RATE (LB/HR)	280.68
ADDITIVE FEED/RATE (LB/HR)	.00
FUEL HHV (BTU/LB)	12837.00
TOTAL HEAT INPUT (MBTU/HR)	4.57
PRIMARY AIR FLOW (LB/HR)	315.07
PRIMARY AIR TEMP. (F)	82.17
SECONDARY AIR FLOW (LB/HR)	3184.63
SECONDARY AIR TEMP. (F)	1249.21
TRANSPORT AIR FLOW (LB/HR)	.00
OXYGEN IN FLUE GAS (PCT)	5.80
PERCENT EXCESS AIR	28.74
LOWER FURNACE PEAK FLAME TEMP. (F)	2907.61
LOWER FURNACE RESIDENCE TIME (SEC)	1.12

WATERWALL TEST PANELS

PANEL P1 SURFACE TEMP. (F)	706.56
PANEL P2 SURFACE TEMP. (F)	643.37
PANEL P3 SURFACE TEMP. (F)	704.70
PANEL P4 SURFACE TEMP. (F)	702.75

SUPERHEATER PROBES

DUCT 1 GAS TEMPERATURE (F)	2292.03
DUCT 2 GAS TEMPERATURE (F)	2137.23
DUCT 3 GAS TEMPERATURE (F)	2001.72
DUCT 4 GAS TEMPERATURE (F)	1867.44
EROSION DUCT GAS TEMP. (F)	1320.00
DUCT 1 GAS VELOCITY (FT/SEC)	73.00
DUCT 2 GAS VELOCITY (FT/SEC)	68.90
DUCT 3 GAS VELOCITY (FT/SEC)	65.30
DUCT 4 GAS VELOCITY (FT/SEC)	61.74
ER.DUCT GAS VEL.[1] (FT/SEC)	220.35
ER.DUCT GAS VEL.[2] (FT/SEC)	238.52

ASH

INPUT (LB/HR)	19.65
DUST LOADING (LB/HR)	10.00
CARBON CONVERSION (PCT)	100.000
CARBON HEAT LOSS (PCT)	.000

METHOD 1-----

FLUE GAS FLOW RATE (LB/HR)	3761.412	
COMPOSITION (MOLES/HR), (PERCENT)		
OXYGEN	5.802	4.56
CARBON DIOXIDE	16.631	13.07
WATER	9.881	7.77
SULFUR DIOXIDE	.263	.21
NITROGEN	94.618	74.39

METHOD 2-----

FLUE GAS FLOW RATE (LB/HR)	4061.813	
COMPOSITION (MOLES/HR), PERCENT		
OXYGEN	7.986	5.80
CARBON DIOXIDE	16.631	12.08
WATER	10.078	7.32
SULFUR DIOXIDE	.263	.19
NITROGEN	102.725	74.61

HEAT OUT

	KBTU/HR	PCT
HEAT LOSS FROM REFRACTORY	234.133	5.12
HEAT LOSS FROM PANELS	489.441	10.71
HEAT LOSS FROM WATER COOLED FRAME	159.363	3.49
HEAT LOSS FROM FLY ASH	5.525	.12
HEAT LOSS FROM UNBURNT CARBON	.000	.00
HEAT LOSS FROM ROOF	54.685	1.20
HEAT LOSS FROM S.H. TRANSITION	125.135	2.74
HEAT LOSS FROM S.H. FRAME	91.164	2.00
HEAT LOSS FROM S.H. DUCT	137.107	3.00
HEAT LOSS FROM OBS. PORT	64.402	1.41
HEAT LOSS FROM BURNER	263.135	5.76
HEAT LOSS FROM FURNACE BOTTOM LEFT	56.138	1.23
HEAT LOSS FROM FURNACE BOTTOM RIGHT	56.138	1.23
HEAT LOSS FROM FLUE GAS, [METHOD 1]	2495.988	54.62
HEAT LOSS FROM FLUE GAS, [METHOD 2]	2699.513	59.08

METHOD 1-----TOTAL MATERIAL INPUT (LB/HR)	3780.39
TOTAL MATERIAL OUTPUT (LB/HR)	3780.41
MATERIAL UNACCOUNTED FOR	.00
TOTAL HEAT INPUT (MBTU/HR)	4.57
TOTAL HEAT OUTPUT (MBTU/HR)	4.27
HEAT UNACCOUNTED FOR (PCT)	6.48

METHOD 2-----TOTAL MATERIAL INPUT (LB/HR)	4081.46
TOTAL MATERIAL OUTPUT (LB/HR)	4080.81
MATERIAL UNACCOUNTED FOR (PCT)	.02

TOTAL HEAT OUTPUT (MBTU/HR)	4.48
HEAT UNACCOUNTED FOR (PCT)	2.03

RESIDENCE TIME ALONG GAS STREAM

LOCATION	TEMP. (F)	TIME, SEC.
SUCTION PORT L1	2908.	.258
SUCTION PORT L2	2830.	.368
SUCTION PORT L3	2787.	.473
SUCTION PORT L4	2686.	.690
SUCTION PORT L5	2477.	1.115
S.H DUCT 1A	2292.	1.315
S.H DUCT 2C	2137.	1.350
S.H DUCT 3E	2002.	1.384
S.H DUCT 4G	1867.	1.445
DUST LOADING PORT	1320.	1.678

WATSON JADER BASELINE TEST 1

COMBUSTION DATA

FUEL FEED RATE (LB/HR)	266.90
ADDITIVE FEED/RATE (LB/HR)	.00
FUEL HHV (BTU/LB)	13121.00
TOTAL HEAT INPUT (MBTU/HR)	4.46
PRIMARY AIR FLOW (LB/HR)	300.30
PRIMARY AIR TEMP. (F)	79.65
SECONDARY AIR FLOW (LB/HR)	2930.53
SECONDARY AIR TEMP. (F)	1342.24
TRANSPORT AIR FLOW (LB/HR)	.00
OXYGEN IN FLUE GAS (PCT)	4.47
PERCENT EXCESS AIR	18.32
LOWER FURNACE PEAK FLAME TEMP. (F)	2896.00
LOWER FURNACE RESIDENCE TIME (SEC)	1.22

WATERWALL TEST PANELS

PANEL P1 SURFACE TEMP. (F)	712.12
PANEL P2 SURFACE TEMP. (F)	694.17
PANEL P3 SURFACE TEMP. (F)	704.13
PANEL P4 SURFACE TEMP. (F)	701.79

SUPERHEATER PROBES

DUCT 1 GAS TEMPERATURE (F)	2276.30
DUCT 2 GAS TEMPERATURE (F)	2159.97
DUCT 3 GAS TEMPERATURE (F)	2043.23
DUCT 4 GAS TEMPERATURE (F)	1874.42
EROSION DUCT GAS TEMP. (F)	1296.00
DUCT 1 GAS VELOCITY (FT/SEC)	66.73
DUCT 2 GAS VELOCITY (FT/SEC)	63.89
DUCT 3 GAS VELOCITY (FT/SEC)	61.05
DUCT 4 GAS VELOCITY (FT/SEC)	56.93
ER.DUCT GAS VEL.[1] (FT/SEC)	199.84
ER.DUCT GAS VEL.[2] (FT/SEC)	215.31

ASH

INPUT (LB/HR)	23.49
DUST LOADING (LB/HR)	12.50
CARBON CONVERSION (PCT)	100.000
CARBON HEAT LOSS (PCT)	.000

METHOD 1-----

FLUE GAS FLOW RATE (LB/HR)	3474.874	
COMPOSITION (MOLES/HR), (PERCENT)		
OXYGEN	3.742	3.20
CARBON DIOXIDE	16.659	14.25
WATER	8.946	7.65
SULFUR DIOXIDE	.242	.21
NITROGEN	87.344	74.70

METHOD 2-----

FLUE GAS FLOW RATE (LB/HR)	3734.196	
COMPOSITION (MOLES/HR), PERCENT		
OXYGEN	5.627	4.47
CARBON DIOXIDE	16.659	13.22
WATER	9.116	7.24
SULFUR DIOXIDE	.242	.19
NITROGEN	94.342	74.88

	KBTU/HR	PCT
HEAT OUT		
HEAT LOSS FROM REFRACTORY	240.664	5.39
HEAT LOSS FROM PANELS	456.157	10.22
HEAT LOSS FROM WATER COOLED FRAME	163.488	3.66
HEAT LOSS FROM FLY ASH	6.865	.15
HEAT LOSS FROM UNBURNT CARBON	.000	.00
HEAT LOSS FROM ROOF	56.921	1.28
HEAT LOSS FROM S.H. TRANSITION	120.228	2.69
HEAT LOSS FROM S.H. FRAME	92.731	2.08
HEAT LOSS FROM S.H. DUCT	116.280	2.60
HEAT LOSS FROM OBS. PORT	64.434	1.44
HEAT LOSS FROM BURNER	268.549	6.02
HEAT LOSS FROM FURNACE BOTTOM LEFT	87.012	1.95
HEAT LOSS FROM FURNACE BOTTOM RIGHT	87.012	1.95
HEAT LOSS FROM FLUE GAS, [METHOD 1]	2277.058	51.01
HEAT LOSS FROM FLUE GAS, [METHOD 2]	2451.299	54.91

METHOD 1-----TOTAL MATERIAL INPUT (LB/HR)	3497.74
TOTAL MATERIAL OUTPUT (LB/HR)	3497.87
MATERIAL UNACCOUNTED FOR	.00
TOTAL HEAT INPUT (MBTU/HR)	4.46
TOTAL HEAT OUTPUT (MBTU/HR)	4.08
HEAT UNACCOUNTED FOR (PCT)	8.63

METHOD 2-----TOTAL MATERIAL INPUT (LB/HR)	3757.69
TOTAL MATERIAL OUTPUT (LB/HR)	3757.20
MATERIAL UNACCOUNTED FOR (PCT)	.01

TOTAL HEAT OUTPUT (MBTU/HR)	4.25
HEAT UNACCOUNTED FOR (PCT)	4.72

RESIDENCE TIME ALONG GAS STREAM

LOCATION	TEMP. (F)	TIME, SEC.
SUCTION PORT L1	2896.	.281
SUCTION PORT L2	2804.	.402
SUCTION PORT L3	2774.	.516
SUCTION PORT L4	2637.	.756
SUCTION PORT L5	2508.	1.219
S.H DUCT 1A	2276.	1.436
S.H DUCT 2C	2160.	1.474
S.H DUCT 3E	2043.	1.511
S.H DUCT 4G	1874.	1.577
DUST LOADING PORT	1296.	1.832

WATSON JADER BASELINE TEST 2

COMBUSTION DATA

FUEL FEED RATE (LB/HR)	286.43
ADDITIVE FEED/RATE (LB/HR)	.00
FUEL HHV (BTU/LB)	13121.00
TOTAL HEAT INPUT (MBTU/HR)	4.81
PRIMARY AIR FLOW (LB/HR)	301.90
PRIMARY AIR TEMP. (F)	85.52
SECONDARY AIR FLOW (LB/HR)	3133.85
SECONDARY AIR TEMP. (F)	1374.94
TRANSPORT AIR FLOW (LB/HR)	.00
OXYGEN IN FLUE GAS (PCT)	4.30
PERCENT EXCESS AIR	17.24
LOWER FURNACE PEAK FLAME TEMP. (F)	2949.25
LOWER FURNACE RESIDENCE TIME (SEC)	1.13

WATERWALL TEST PANELS

PANEL P1 SURFACE TEMP. (F)	707.35
PANEL P2 SURFACE TEMP. (F)	645.53
PANEL P3 SURFACE TEMP. (F)	703.95
PANEL P4 SURFACE TEMP. (F)	702.47

SUPERHEATER PROBES

DUCT 1 GAS TEMPERATURE (F)	2394.66
DUCT 2 GAS TEMPERATURE (F)	2290.30
DUCT 3 GAS TEMPERATURE (F)	2152.66
DUCT 4 GAS TEMPERATURE (F)	1897.72
EROSION DUCT GAS TEMP. (F)	1375.00
DUCT 1 GAS VELOCITY (FT/SEC)	74.05
DUCT 2 GAS VELOCITY (FT/SEC)	71.35
DUCT 3 GAS VELOCITY (FT/SEC)	67.78
DUCT 4 GAS VELOCITY (FT/SEC)	61.16
ER.DUCT GAS VEL.[1] (FT/SEC)	222.15
ER.DUCT GAS VEL.[2] (FT/SEC)	238.97

ASH

INPUT (LB/HR)	25.21
DUST LOADING (LB/HR)	13.00
CARBON CONVERSION (PCT)	100.000
CARBON HEAT LOSS (PCT)	.000

METHOD 1-----

FLUE GAS FLOW RATE (LB/HR)	3697.635	
COMPOSITION (MOLES/HR), (PERCENT)		
OXYGEN	3.787	3.04
CARBON DIOXIDE	17.878	14.37
WATER	9.580	7.70
SULFUR DIOXIDE	.260	.21
NITROGEN	92.885	74.67

METHOD 2-----

FLUE GAS FLOW RATE (LB/HR)	3967.550	
COMPOSITION (MOLES/HR), PERCENT		
OXYGEN	5.749	4.30
CARBON DIOXIDE	17.878	13.36
WATER	9.757	7.29
SULFUR DIOXIDE	.260	.19
NITROGEN	100.169	74.86

HEAT OUT

	KBTU/HR	PCT
HEAT LOSS FROM REFRACTORY	251.453	5.23
HEAT LOSS FROM PANELS	502.791	10.46
HEAT LOSS FROM WATER COOLED FRAME	198.933	4.14
HEAT LOSS FROM FLY ASH	7.505	.16
HEAT LOSS FROM UNBURNT CARBON	.000	.00
HEAT LOSS FROM ROOF	63.913	1.33
HEAT LOSS FROM S.H. TRANSITION	132.644	2.76
HEAT LOSS FROM S.H. FRAME	126.924	2.64
HEAT LOSS FROM S.H. DUCT	130.899	2.72
HEAT LOSS FROM OBS. PORT	66.144	1.38
HEAT LOSS FROM BURNER	258.507	5.38
HEAT LOSS FROM FURNACE BOTTOM LEFT	58.367	1.21
HEAT LOSS FROM FURNACE BOTTOM RIGHT	58.367	1.21
HEAT LOSS FROM FLUE GAS, [METHOD 1]	2569.257	53.43
HEAT LOSS FROM FLUE GAS, [METHOD 2]	2762.964	57.46

METHOD 1-----TOTAL MATERIAL INPUT (LB/HR)	3722.18
TOTAL MATERIAL OUTPUT (LB/HR)	3722.14
MATERIAL UNACCOUNTED FOR	.00
TOTAL HEAT INPUT (MBTU/HR)	4.81
TOTAL HEAT OUTPUT (MBTU/HR)	4.47
HEAT UNACCOUNTED FOR (PCT)	7.12

METHOD 2-----TOTAL MATERIAL INPUT (LB/HR)	3992.76
TOTAL MATERIAL OUTPUT (LB/HR)	3992.05
MATERIAL UNACCOUNTED FOR (PCT)	.02

TOTAL HEAT OUTPUT (MBTU/HR)	4.66
HEAT UNACCOUNTED FOR (PCT)	3.10

RESIDENCE TIME ALONG GAS STREAM

LOCATION	TEMP. (F)	TIME, SEC.
SUCTION PORT L1	2949.	.260
SUCTION PORT L2	2877.	.371
SUCTION PORT L3	2818.	.477
SUCTION PORT L4	2723.	.698
SUCTION PORT L5	2589.	1.121
S.H DUCT 1A	2395.	1.319
S.H DUCT 2C	2290.	1.353
S.H DUCT 3E	2153.	1.387
S.H DUCT 4G	1898.	1.447
DUST LOADING PORT	1375.	1.681

WATSON JADER TEST 3

COMBUSTION DATA

FUEL FEED RATE (LB/HR)	301.56
ADDITIVE FEED/RATE (LB/HR)	.00
FUEL HHV (BTU/LB)	13121.00
TOTAL HEAT INPUT (MBTU/HR)	5.05
PRIMARY AIR FLOW (LB/HR)	299.97
PRIMARY AIR TEMP. (F)	85.07
SECONDARY AIR FLOW (LB/HR)	3308.19
SECONDARY AIR TEMP. (F)	1350.32
TRANSPORT AIR FLOW (LB/HR)	.00
OXYGEN IN FLUE GAS (PCT)	4.30
PERCENT EXCESS AIR	16.95
LOWER FURNACE PEAK FLAME TEMP. (F)	3013.33
LOWER FURNACE RESIDENCE TIME (SEC)	1.06

WATERWALL TEST PANELS

PANEL P1 SURFACE TEMP. (F)	706.89
PANEL P2 SURFACE TEMP. (F)	700.28
PANEL P3 SURFACE TEMP. (F)	704.43
PANEL P4 SURFACE TEMP. (F)	702.56

SUPERHEATER PROBES

DUCT 1 GAS TEMPERATURE (F)	2410.54
DUCT 2 GAS TEMPERATURE (F)	2277.21
DUCT 3 GAS TEMPERATURE (F)	2110.64
DUCT 4 GAS TEMPERATURE (F)	1880.00
EROSION DUCT GAS TEMP. (F)	1363.00
DUCT 1 GAS VELOCITY (FT/SEC)	78.21
DUCT 2 GAS VELOCITY (FT/SEC)	74.58
DUCT 3 GAS VELOCITY (FT/SEC)	70.04
DUCT 4 GAS VELOCITY (FT/SEC)	63.76
ER.DUCT GAS VEL.[1] (FT/SEC)	231.79
ER.DUCT GAS VEL.[2] (FT/SEC)	249.95

ASH

INPUT (LB/HR)	26.54
DUST LOADING (LB/HR)	14.00
CARBON CONVERSION (PCT)	100.000
CARBON HEAT LOSS (PCT)	.000

METHOD 1-----

FLUE GAS FLOW RATE (LB/HR)	3883.867	
COMPOSITION (MOLES/HR), (PERCENT)		
OXYGEN	3.921	3.00
CARBON DIOXIDE	18.822	14.41
WATER	10.080	7.72
SULFUR DIOXIDE	.273	.21
NITROGEN	97.546	74.67

METHOD 2-----

FLUE GAS FLOW RATE (LB/HR)	4177.126	
COMPOSITION (MOLES/HR), PERCENT		
OXYGEN	6.052	4.30
CARBON DIOXIDE	18.822	13.36
WATER	10.273	7.29
SULFUR DIOXIDE	.273	.19
NITROGEN	105.460	74.86

HEAT OUT

	KBTU/HR	PCT
HEAT LOSS FROM REFRACTORY	267.479	5.30
HEAT LOSS FROM PANELS	567.634	11.25
HEAT LOSS FROM WATER COOLED FRAME	211.856	4.20
HEAT LOSS FROM FLY ASH	8.139	.16
HEAT LOSS FROM UNBURNT CARBON	.000	.00
HEAT LOSS FROM ROOF	73.434	1.46
HEAT LOSS FROM S.H. TRANSITION	167.699	3.32
HEAT LOSS FROM S.H. FRAME	135.567	2.69
HEAT LOSS FROM S.H. DUCT	151.351	3.00
HEAT LOSS FROM OBS. PORT	60.805	1.21
HEAT LOSS FROM BURNER	217.098	4.30
HEAT LOSS FROM FURNACE BOTTOM LEFT	44.993	.89
HEAT LOSS FROM FURNACE BOTTOM RIGHT	44.993	.89
HEAT LOSS FROM FLUE GAS, [METHOD 1]	2720.283	53.92
HEAT LOSS FROM FLUE GAS, [METHOD 2]	2932.656	58.13

METHOD 1-----TOTAL MATERIAL INPUT (LB/HR)	3909.71
TOTAL MATERIAL OUTPUT (LB/HR)	3909.37
MATERIAL UNACCOUNTED FOR	.01
TOTAL HEAT INPUT (MBTU/HR)	5.05
TOTAL HEAT OUTPUT (MBTU/HR)	4.70
HEAT UNACCOUNTED FOR (PCT)	6.74

METHOD 2-----TOTAL MATERIAL INPUT (LB/HR)	4203.67
TOTAL MATERIAL OUTPUT (LB/HR)	4202.63
MATERIAL UNACCOUNTED FOR (PCT)	.02

TOTAL HEAT OUTPUT (MBTU/HR)	4.92
HEAT UNACCOUNTED FOR (PCT)	2.53

RESIDENCE TIME ALONG GAS STREAM

LOCATION	TEMP. (F)	TIME, SEC.
SUCTION PORT L1	3013.	.243
SUCTION PORT L2	2920.	.347
SUCTION PORT L3	2849.	.447
SUCTION PORT L4	2782.	.654
SUCTION PORT L5	2648.	1.050
S.H DUCT 1A	2411.	1.235
S.H DUCT 2C	2277.	1.268
S.H DUCT 3E	2111.	1.300
S.H DUCT 4G	1880.	1.358
DUST LOADING PORT	1363.	1.582

WATSON: JADER COAL BSELINE TEST 4

COMBUSTION DATA

FUEL FEED RATE (LB/HR)	295.41
ADDITIVE FEED/RATE (LB/HR)	.00
FUEL HHV (BTU/LB)	13121.00
TOTAL HEAT INPUT (MBTU/HR)	4.97
PRIMARY AIR FLOW (LB/HR)	305.34
PRIMARY AIR TEMP. (F)	93.81
SECONDARY AIR FLOW (LB/HR)	3329.35
SECONDARY AIR TEMP. (F)	1355.14
TRANSPORT AIR FLOW (LB/HR)	.00
OXYGEN IN FLUE GAS (PCT)	4.44
PERCENT EXCESS AIR	20.26
LOWER FURNACE PEAK FLAME TEMP. (F)	3013.31
LOWER FURNACE RESIDENCE TIME (SEC)	1.06

WATERWALL TEST PANELS

PANEL P1 SURFACE TEMP. (F)	706.66
PANEL P2 SURFACE TEMP. (F)	665.53
PANEL P3 SURFACE TEMP. (F)	704.81
PANEL P4 SURFACE TEMP. (F)	703.14

SUPERHEATER PROBES

DUCT 1 GAS TEMPERATURE (F)	2394.91
DUCT 2 GAS TEMPERATURE (F)	2213.52
DUCT 3 GAS TEMPERATURE (F)	2042.63
DUCT 4 GAS TEMPERATURE (F)	1885.74
EROSION DUCT GAS TEMP. (F)	1353.00
DUCT 1 GAS VELOCITY (FT/SEC)	78.28
DUCT 2 GAS VELOCITY (FT/SEC)	73.31
DUCT 3 GAS VELOCITY (FT/SEC)	68.62
DUCT 4 GAS VELOCITY (FT/SEC)	64.32
ER.DUCT GAS VEL.[1] (FT/SEC)	231.99
ER.DUCT GAS VEL.[2] (FT/SEC)	245.59

ASH

INPUT (LB/HR)	26.00
DUST LOADING (LB/HR)	14.00
CARBON CONVERSION (PCT)	100.000
CARBON HEAT LOSS (PCT)	.000

METHOD 1-----

FLUE GAS FLOW RATE (LB/HR)	3904.805	
COMPOSITION (MOLES/HR), (PERCENT)		
OXYGEN	4.568	3.47
CARBON DIOXIDE	18.438	14.02
WATER	9.940	7.56
SULFUR DIOXIDE	.268	.20
NITROGEN	98.259	74.74

METHOD 2-----

FLUE GAS FLOW RATE (LB/HR)	4125.743	
COMPOSITION (MOLES/HR), PERCENT		
OXYGEN	6.174	4.44
CARBON DIOXIDE	18.438	13.25
WATER	10.085	7.25
SULFUR DIOXIDE	.268	.19
NITROGEN	104.221	74.88

HEAT OUT

	KBTU/HR	PCT
HEAT LOSS FROM REFRACTORY	254.269	5.12
HEAT LOSS FROM PANELS	548.569	11.04
HEAT LOSS FROM WATER COOLED FRAME	176.269	3.55
HEAT LOSS FROM FLY ASH	8.054	.16
HEAT LOSS FROM UNBURNT CARBON	.000	.00
HEAT LOSS FROM ROOF	72.009	1.45
HEAT LOSS FROM S.H. TRANSITION	156.573	3.15
HEAT LOSS FROM S.H. FRAME	130.827	2.63
HEAT LOSS FROM S.H. DUCT	156.348	3.15
HEAT LOSS FROM OBS. PORT	69.462	1.40
HEAT LOSS FROM BURNER	194.152	3.91
HEAT LOSS FROM FURNACE BOTTOM LEFT	38.352	.77
HEAT LOSS FROM FURNACE BOTTOM RIGHT	38.352	.77
HEAT LOSS FROM FLUE GAS, [METHOD 1]	2708.283	54.52
HEAT LOSS FROM FLUE GAS, [METHOD 2]	2866.440	57.70

METHOD 1-----TOTAL MATERIAL INPUT (LB/HR)	3930.10
TOTAL MATERIAL OUTPUT (LB/HR)	3929.81
MATERIAL UNACCOUNTED FOR	.01
TOTAL HEAT INPUT (MBTU/HR)	4.97
TOTAL HEAT OUTPUT (MBTU/HR)	4.58
HEAT UNACCOUNTED FOR (PCT)	7.83

METHOD 2-----TOTAL MATERIAL INPUT (LB/HR)	4151.74
TOTAL MATERIAL OUTPUT (LB/HR)	4150.74
MATERIAL UNACCOUNTED FOR (PCT)	.02

TOTAL HEAT OUTPUT (MBTU/HR)	4.74
HEAT UNACCOUNTED FOR (PCT)	4.64

RESIDENCE TIME ALONG GAS STREAM

LOCATION	TEMP. (F)	TIME, SEC.
SUCTION PORT L1	3013.	.242
SUCTION PORT L2	2886.	.346
SUCTION PORT L3	2809.	.446
SUCTION PORT L4	2696.	.656
SUCTION PORT L5	2623.	1.056
S.H DUCT 1A	2395.	1.242
S.H DUCT 2C	2214.	1.275
S.H DUCT 3E	2043.	1.308
S.H DUCT 4G	1886.	1.367
DUST LOADING PORT	1353.	1.595

WATSON: JADER COAL LOW O2 T1

COMBUSTION DATA

FUEL FEED RATE (LB/HR)	299.94
ADDITIVE FEED/RATE (LB/HR)	.00
FUEL HHV (BTU/LB)	13121.00
TOTAL HEAT INPUT (MBTU/HR)	4.97
PRIMARY AIR FLOW (LB/HR)	309.96
PRIMARY AIR TEMP. (F)	93.43
SECONDARY AIR FLOW (LB/HR)	3060.19
SECONDARY AIR TEMP. (F)	1399.32
TRANSPORT AIR FLOW (LB/HR)	.00
OXYGEN IN FLUE GAS (PCT)	3.60
PERCENT EXCESS AIR	9.83
LOWER FURNACE PEAK FLAME TEMP. (F)	2982.68
LOWER FURNACE RESIDENCE TIME (SEC)	1.13

WATERWALL TEST PANELS

PANEL P1 SURFACE TEMP. (F)	705.92
PANEL P2 SURFACE TEMP. (F)	675.33
PANEL P3 SURFACE TEMP. (F)	705.07
PANEL P4 SURFACE TEMP. (F)	702.27

SUPERHEATER PROBES

DUCT 1 GAS TEMPERATURE (F)	2421.24
DUCT 2 GAS TEMPERATURE (F)	2329.81
DUCT 3 GAS TEMPERATURE (F)	2164.37
DUCT 4 GAS TEMPERATURE (F)	1976.02
EROSION DUCT GAS TEMP. (F)	1409.00
DUCT 1 GAS VELOCITY (FT/SEC)	73.49
DUCT 2 GAS VELOCITY (FT/SEC)	71.16
DUCT 3 GAS VELOCITY (FT/SEC)	66.94
DUCT 4 GAS VELOCITY (FT/SEC)	62.14
ER.DUCT GAS VEL.[1] (FT/SEC)	222.48
ER.DUCT GAS VEL.[2] (FT/SEC)	244.62

ASH

INPUT (LB/HR)	26.39
DUST LOADING (LB/HR)	14.00
CARBON CONVERSION (PCT)	100.000
CARBON HEAT LOSS (PCT)	.000

METHOD 1-----

FLUE GAS FLOW RATE (LB/HR)	3644.339	
COMPOSITION (MOLES/HR), (PERCENT)		
OXYGEN	2.310	1.89
CARBON DIOXIDE	18.721	15.31
WATER	9.882	8.08
SULFUR DIOXIDE	.272	.22
NITROGEN	91.122	74.50

METHOD 2-----

FLUE GAS FLOW RATE (LB/HR)	3993.107	
COMPOSITION (MOLES/HR), PERCENT		
OXYGEN	4.845	3.60
CARBON DIOXIDE	18.721	13.92
WATER	10.111	7.52
SULFUR DIOXIDE	.272	.20
NITROGEN	100.533	74.76

	KBTU/HR	PCT
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HEAT OUT

HEAT LOSS FROM REFRACTORY	259.124	5.21
HEAT LOSS FROM PANELS	524.173	10.54
HEAT LOSS FROM WATER COOLED FRAME	196.957	3.96
HEAT LOSS FROM FLY ASH	8.147	.16
HEAT LOSS FROM UNBURNT CARBON	.000	.00
HEAT LOSS FROM ROOF	74.413	1.50
HEAT LOSS FROM S.H. TRANSITION	136.063	2.74
HEAT LOSS FROM S.H. FRAME	131.100	2.64
HEAT LOSS FROM S.H. DUCT	134.487	2.70
HEAT LOSS FROM OBS. PORT	74.921	1.51
HEAT LOSS FROM BURNER	326.661	6.57
HEAT LOSS FROM FURNACE BOTTOM LEFT	92.658	1.86
HEAT LOSS FROM FURNACE BOTTOM RIGHT	92.658	1.86
HEAT LOSS FROM FLUE GAS, [METHOD 1]	2553.835	51.34
HEAT LOSS FROM FLUE GAS, [METHOD 2]	2807.247	56.43

METHOD 1-----TOTAL MATERIAL INPUT (LB/HR)	3670.08
TOTAL MATERIAL OUTPUT (LB/HR)	3669.34
MATERIAL UNACCOUNTED FOR	.02

TOTAL HEAT INPUT (MBTU/HR)	4.97
TOTAL HEAT OUTPUT (MBTU/HR)	4.65
HEAT UNACCOUNTED FOR (PCT)	6.54

METHOD 2-----TOTAL MATERIAL INPUT (LB/HR)	4019.50
TOTAL MATERIAL OUTPUT (LB/HR)	4018.11
MATERIAL UNACCOUNTED FOR (PCT)	.03

TOTAL HEAT OUTPUT (MBTU/HR)	4.90
HEAT UNACCOUNTED FOR (PCT)	1.44

RESIDENCE TIME ALONG GAS STREAM

LOCATION	TEMP. (F)	TIME, SEC.
SUCTION PORT L1	2983.	.262
SUCTION PORT L2	2910.	.374
SUCTION PORT L3	2859.	.480
SUCTION PORT L4	2753.	.702
SUCTION PORT L5	2607.	1.130
S.H DUCT 1A	2421.	1.329
S.H DUCT 2C	2330.	1.363
S.H DUCT 3E	2164.	1.396
S.H DUCT 4G	1976.	1.455
DUST LOADING PORT	1409.	1.682

WATSON: JADER COAL ~ LOW O2 T2

COMBUSTION DATA

FUEL FEED RATE (LB/HR)	298.54
ADDITIVE FEED/RATE (LB/HR)	.00
FUEL HHV (BTU/LB)	13121.00
TOTAL HEAT INPUT (MBTU/HR)	4.95
PRIMARY AIR FLOW (LB/HR)	309.66
PRIMARY AIR TEMP. (F)	88.27
SECONDARY AIR FLOW (LB/HR)	3025.36
SECONDARY AIR TEMP. (F)	1399.52
TRANSPORT AIR FLOW (LB/HR)	.00
OXYGEN IN FLUE GAS (PCT)	3.75
PERCENT EXCESS AIR	9.19
LOWER FURNACE PEAK FLAME TEMP. (F)	2988.95
LOWER FURNACE RESIDENCE TIME (SEC)	1.15

WATERWALL TEST PANELS

PANEL P1 SURFACE TEMP. (F)	704.82
PANEL P2 SURFACE TEMP. (F)	695.38
PANEL P3 SURFACE TEMP. (F)	704.10
PANEL P4 SURFACE TEMP. (F)	703.23

SUPERHEATER PROBES

DUCT 1 GAS TEMPERATURE (F)	2357.38
DUCT 2 GAS TEMPERATURE (F)	2256.45
DUCT 3 GAS TEMPERATURE (F)	2122.38
DUCT 4 GAS TEMPERATURE (F)	1934.16
EROSION DUCT GAS TEMP. (F)	1367.00
DUCT 1 GAS VELOCITY (FT/SEC)	71.13
DUCT 2 GAS VELOCITY (FT/SEC)	68.58
DUCT 3 GAS VELOCITY (FT/SEC)	65.20
DUCT 4 GAS VELOCITY (FT/SEC)	60.45
ER.DUCT GAS VEL.[1] (FT/SEC)	215.26
ER.DUCT GAS VEL.[2] (FT/SEC)	240.05

ASH

INPUT (LB/HR)	26.27
DUST LOADING (LB/HR)	14.00
CARBON CONVERSION (PCT)	100.000
CARBON HEAT LOSS (PCT)	.000

METHOD 1-----

FLUE GAS FLOW RATE (LB/HR)	3607.934	
COMPOSITION (MOLES/HR), (PERCENT)		
OXYGEN	2.158	1.78
CARBON DIOXIDE	18.634	15.39
WATER	9.823	8.11
SULFUR DIOXIDE	.271	.22
NITROGEN	90.173	74.49

METHOD 2-----

FLUE GAS FLOW RATE (LB/HR)	4007.311	
COMPOSITION (MOLES/HR), PERCENT		
OXYGEN	5.061	3.75
CARBON DIOXIDE	18.634	13.80
WATER	10.086	7.47
SULFUR DIOXIDE	.271	.20
NITROGEN	100.950	74.78

HEAT OUT

	KBTU/HR	PCT
HEAT LOSS FROM REFRACTORY	265.126	5.36
HEAT LOSS FROM PANELS	547.852	11.07
HEAT LOSS FROM WATER COOLED FRAME	190.420	3.85
HEAT LOSS FROM FLY ASH	7.942	.16
HEAT LOSS FROM UNBURNT CARBON	.000	.00
HEAT LOSS FROM ROOF	98.183	1.98
HEAT LOSS FROM S.H. TRANSITION	157.023	3.17
HEAT LOSS FROM S.H. FRAME	148.458	3.00
HEAT LOSS FROM S.H. DUCT	153.928	3.11
HEAT LOSS FROM OBS. PORT	68.559	1.39
HEAT LOSS FROM BURNER	308.841	6.24
HEAT LOSS FROM FURNACE BOTTOM LEFT	83.857	1.69
HEAT LOSS FROM FURNACE BOTTOM RIGHT	83.857	1.69
HEAT LOSS FROM FLUE GAS, [METHOD 1]	2452.848	49.57
HEAT LOSS FROM FLUE GAS, [METHOD 2]	2733.234	55.23

METHOD 1-----TOTAL MATERIAL INPUT (LB/HR)	3633.56
TOTAL MATERIAL OUTPUT (LB/HR)	3632.93
MATERIAL UNACCOUNTED FOR	.02
TOTAL HEAT INPUT (MBTU/HR)	4.95
TOTAL HEAT OUTPUT (MBTU/HR)	4.60
HEAT UNACCOUNTED FOR (PCT)	7.09

METHOD 2-----TOTAL MATERIAL INPUT (LB/HR)	4033.59
TOTAL MATERIAL OUTPUT (LB/HR)	4032.31
MATERIAL UNACCOUNTED FOR (PCT)	.03

TOTAL HEAT OUTPUT (MBTU/HR)	4.88
HEAT UNACCOUNTED FOR (PCT)	1.43

RESIDENCE TIME ALONG GAS STREAM

LOCATION	TEMP. (F)	TIME, SEC.
SUCTION PORT L1	2989.	.264
SUCTION PORT L2	2897.	.377
SUCTION PORT L3	2830.	.486
SUCTION PORT L4	2792.	.710
SUCTION PORT L5	2572.	1.141
S.H DUCT 1A	2357.	1.346
S.H DUCT 2C	2256.	1.380
S.H DUCT 3E	2122.	1.414
S.H DUCT 4G	1934.	1.473
DUST LOADING PORT	1367.	1.704

WATSON: JADER COAL - LOW O2 T3

COMBUSTION DATA

FUEL FEED RATE (LB/HR)	283.67
ADDITIVE FEED/RATE (LB/HR)	.00
FUEL HHV (BTU/LB)	13121.00
TOTAL HEAT INPUT (MBTU/HR)	4.35
PRIMARY AIR FLOW (LB/HR)	302.85
PRIMARY AIR TEMP. (F)	80.93
SECONDARY AIR FLOW (LB/HR)	2800.44
SECONDARY AIR TEMP. (F)	947.22
TRANSPORT AIR FLOW (LB/HR)	.00
OXYGEN IN FLUE GAS (PCT)	3.20
PERCENT EXCESS AIR	6.97
LOWER FURNACE PEAK FLAME TEMP. (F)	2977.64
LOWER FURNACE RESIDENCE TIME (SEC)	1.25

WATERWALL TEST PANELS

PANEL P1 SURFACE TEMP. (F)	623.56
PANEL P2 SURFACE TEMP. (F)	677.93
PANEL P3 SURFACE TEMP. (F)	704.10
PANEL P4 SURFACE TEMP. (F)	702.59

SUPERHEATER PROBES

DUCT 1 GAS TEMPERATURE (F)	2284.47
DUCT 2 GAS TEMPERATURE (F)	2195.18
DUCT 3 GAS TEMPERATURE (F)	2034.70
DUCT 4 GAS TEMPERATURE (F)	1844.71
EROSION DUCT GAS TEMP. (F)	1330.00
DUCT 1 GAS VELOCITY (FT/SEC)	64.53
DUCT 2 GAS VELOCITY (FT/SEC)	62.43
DUCT 3 GAS VELOCITY (FT/SEC)	58.66
DUCT 4 GAS VELOCITY (FT/SEC)	54.19
ER.DUCT GAS VEL.[1] (FT/SEC)	196.42
ER.DUCT GAS VEL.[2] (FT/SEC)	216.51

ASH

INPUT (LB/HR)	24.96
DUST LOADING (LB/HR)	13.00
CARBON CONVERSION (PCT)	100.000
CARBON HEAT LOSS (PCT)	.000

METHOD 1-----

FLUE GAS FLOW RATE (LB/HR)	3362.876	
COMPOSITION (MOLES/HR), (PERCENT)		
OXYGEN	1.583	1.40
CARBON DIOXIDE	17.706	15.70
WATER	9.291	8.24
SULFUR DIOXIDE	.257	.23
NITROGEN	83.910	74.42

METHOD 2-----

FLUE GAS FLOW RATE (LB/HR)	3693.228	
COMPOSITION (MOLES/HR), PERCENT		
OXYGEN	3.977	3.20
CARBON DIOXIDE	17.706	14.25
WATER	9.508	7.65
SULFUR DIOXIDE	.257	.21
NITROGEN	92.833	74.70

HEAT OUT

	KBTU/HR	PCT
HEAT LOSS FROM REFRACTORY	247.678	5.69
HEAT LOSS FROM PANELS	518.570	11.91
HEAT LOSS FROM WATER COOLED FRAME	173.752	3.99
HEAT LOSS FROM FLY ASH	7.162	.16
HEAT LOSS FROM UNBURNT CARBON	.000	.00
HEAT LOSS FROM ROOF	71.654	1.65
HEAT LOSS FROM S.H. TRANSITION	140.183	3.22
HEAT LOSS FROM S.H. FRAME	116.345	2.67
HEAT LOSS FROM S.H. DUCT	145.261	3.34
HEAT LOSS FROM OBS. PORT	63.253	1.45
HEAT LOSS FROM BURNER	188.724	4.34
HEAT LOSS FROM FURNACE BOTTOM LEFT	47.595	1.09
HEAT LOSS FROM FURNACE BOTTOM RIGHT	47.595	1.09
HEAT LOSS FROM FLUE GAS, [METHOD 1]	2206.607	50.69
HEAT LOSS FROM FLUE GAS, [METHOD 2]	2429.505	55.81

METHOD 1-----TOTAL MATERIAL INPUT (LB/HR)	3386.96
TOTAL MATERIAL OUTPUT (LB/HR)	3386.38
MATERIAL UNACCOUNTED FOR	.02

TOTAL HEAT INPUT (MBTU/HR)	4.35
TOTAL HEAT OUTPUT (MBTU/HR)	4.00
HEAT UNACCOUNTED FOR (PCT)	8.01

METHOD 2-----TOTAL MATERIAL INPUT (LB/HR)	3718.19
TOTAL MATERIAL OUTPUT (LB/HR)	3716.73
MATERIAL UNACCOUNTED FOR (PCT)	.04

TOTAL HEAT OUTPUT (MBTU/HR)	4.23
HEAT UNACCOUNTED FOR (PCT)	2.89

RESIDENCE TIME ALONG GAS STREAM

LOCATION	TEMP. (F)	TIME, SEC.
SUCTION PORT L1	2978.	.285
SUCTION PORT L2	2856.	.407
SUCTION PORT L3	2740.	.526
SUCTION PORT L4	2690.	.773
SUCTION PORT L5	2549.	1.246
S.H DUCT 1A	2284.	1.470
S.H DUCT 2C	2195.	1.508
S.H DUCT 3E	2035.	1.546
S.H DUCT 4G	1845.	1.613
DUST LOADING PORT	1330.	1.871

WATSON : JADER COAL - LOW O2 T4

COMBUSTION DATA

FUEL FEED RATE (LB/HR)	268.52
ADDITIVE FEED/RATE (LB/HR)	.00
FUEL HHV (BTU/LB)	13121.00
TOTAL HEAT INPUT (MBTU/HR)	4.02
PRIMARY AIR FLOW (LB/HR)	314.73
PRIMARY AIR TEMP. (F)	76.16
SECONDARY AIR FLOW (LB/HR)	2678.58
SECONDARY AIR TEMP. (F)	792.23
TRANSPORT AIR FLOW (LB/HR)	.00
OXYGEN IN FLUE GAS (PCT)	3.34
PERCENT EXCESS AIR	8.96
LOWER FURNACE PEAK FLAME TEMP. (F)	2912.32
LOWER FURNACE RESIDENCE TIME (SEC)	1.32

WATERWALL TEST PANELS

PANEL P1 SURFACE TEMP. (F)	700.44
PANEL P2 SURFACE TEMP. (F)	619.20
PANEL P3 SURFACE TEMP. (F)	703.38
PANEL P4 SURFACE TEMP. (F)	701.68

SUPERHEATER PROBES

DUCT 1 GAS TEMPERATURE (F)	2258.39
DUCT 2 GAS TEMPERATURE (F)	2111.91
DUCT 3 GAS TEMPERATURE (F)	1932.22
DUCT 4 GAS TEMPERATURE (F)	1762.33
EROSION DUCT GAS TEMP. (F)	1305.00
DUCT 1 GAS VELOCITY (FT/SEC)	61.60
DUCT 2 GAS VELOCITY (FT/SEC)	58.28
DUCT 3 GAS VELOCITY (FT/SEC)	54.21
DUCT 4 GAS VELOCITY (FT/SEC)	50.36
ER.DUCT GAS VEL.[1] (FT/SEC)	186.66
ER.DUCT GAS VEL.[2] (FT/SEC)	203.75

ASH

INPUT (LB/HR)	23.63
DUST LOADING (LB/HR)	13.00
CARBON CONVERSION (PCT)	100.000
CARBON HEAT LOSS (PCT)	.000

METHOD 1-----

FLUE GAS FLOW RATE (LB/HR)	3238.773	
COMPOSITION (MOLES/HR), (PERCENT)		
OXYGEN	1.895	1.74
CARBON DIOXIDE	16.760	15.42
WATER	8.831	8.13
SULFUR DIOXIDE	.243	.22
NITROGEN	80.934	74.48

METHOD 2-----

FLUE GAS FLOW RATE (LB/HR)	3523.699	
COMPOSITION (MOLES/HR), PERCENT		
OXYGEN	3.966	3.34
CARBON DIOXIDE	16.760	14.13
WATER	9.018	7.60
SULFUR DIOXIDE	.243	.21
NITROGEN	88.623	74.72

HEAT OUT

	KBTU/HR	PCT
HEAT LOSS FROM REFRACTORY	254.370	6.32
HEAT LOSS FROM PANELS	457.829	11.38
HEAT LOSS FROM WATER COOLED FRAME	147.818	3.68
HEAT LOSS FROM FLY ASH	7.092	.18
HEAT LOSS FROM UNBURNT CARBON	.000	.00
HEAT LOSS FROM ROOF	60.133	1.50
HEAT LOSS FROM S.H. TRANSITION	144.675	3.60
HEAT LOSS FROM S.H. FRAME	117.615	2.92
HEAT LOSS FROM S.H. DUCT	139.750	3.47
HEAT LOSS FROM OBS. PORT	55.007	1.37
HEAT LOSS FROM BURNER	118.218	2.94
HEAT LOSS FROM FURNACE BOTTOM LEFT	32.077	.80
HEAT LOSS FROM FURNACE BOTTOM RIGHT	32.077	.80
HEAT LOSS FROM FLUE GAS, [METHOD 1]	2100.776	52.23
HEAT LOSS FROM FLUE GAS, [METHOD 2]	2290.450	56.95

METHOD 1-----TOTAL MATERIAL INPUT (LB/HR)	3261.83
TOTAL MATERIAL OUTPUT (LB/HR)	3261.77
MATERIAL UNACCOUNTED FOR	.00

TOTAL HEAT INPUT (MBTU/HR)	4.02
TOTAL HEAT OUTPUT (MBTU/HR)	3.69
HEAT UNACCOUNTED FOR (PCT)	8.15

METHOD 2-----TOTAL MATERIAL INPUT (LB/HR)	3547.33
TOTAL MATERIAL OUTPUT (LB/HR)	3546.70
MATERIAL UNACCOUNTED FOR (PCT)	.02

TOTAL HEAT OUTPUT (MBTU/HR)	3.88
HEAT UNACCOUNTED FOR (PCT)	3.43

RESIDENCE TIME ALONG GAS STREAM

LOCATION	TEMP. (F)	TIME, SEC.
SUCTION PORT L1	2912.	.301
SUCTION PORT L2	2820.	.430
SUCTION PORT L3	2721.	.554
SUCTION PORT L4	2650.	.813
SUCTION PORT L5	2494.	1.312
S.H DUCT 1A	2258.	1.547
S.H DUCT 2C	2112.	1.588
S.H DUCT 3E	1932.	1.628
S.H DUCT 4G	1762.	1.701
DUST LOADING PORT	1305.	1.980